A
COMPENDIOUS COURSE
OF
PRACTICAL MATHEMATICS,

Particularly Adapted to the
USE OF THE GENTLEMEN
OF THE
ARMY AND *NAVY*.

IN TWO VOLUMES.

For the moſt part tranſlated from the *French* of P. *Hoſte*
Profeſſor of Mathematics in the
Royal Academy of *Thoulon*,
By the late *WILLIAM WEBSTER*.

The THIRD EDITION,

Corrected and improved by S. CLARKE, Teacher of
Mathematics, and Author of *An eaſy Introduction to
the Theory and Practice of Mechanics*.

VOL. II. Containing,

I. Uſe of the GLOBES. II NAVIGATION.	III. The THEORY of Working a Ship.

To which are added,
I. An ALPHABETICAL EXPLANATION of ſuch Sea-Terms and
Phraſes as occur in the Work.
II. An APPENDIX, containing the Deſcription and USE of a
Complete SET or CASE of Pocket-Inſtruments.

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To the Right Honourable

GEORGE,

Lord Viſcount TORRINGTON,

Firſt Lord COMMISSIONER of the

Admiralty, *&c.*

MY LORD,

AS a Treatiſe on Numbers could no where have been ſo properly addreſſed as to that eminent Maſter of Figures the Rt. Honourable Sir *Robert Walpole*, Firſt Lord Commiſſioner of the Treaſury, who has done my *Arithmetick in Epitome* the Honour of his Patronage; nor a *Collection of Mathematical Tracts on the Principles of Military Architecture*, &c. laid ſo rightly as at the Feet of his Grace the Duke of *Argyle*, Maſter-General of the Ordnance, who has likewiſe had the Goodneſs to accept it: So Your Lordſhip will, I hope, excuſe my Ambition in Dedicating this Part of the Work, which regards the Marine, and contains *an Attempt towards a Rationale on the Practical*

Part of Navigation, to Your Lordſhip, who, with ſuch deſerved Honour, preſide in the Naval Affairs of *Great-Britain*.

It is a peculiar Happineſs to a Writer, when his Work ſo naturally points out its Patron; and the Author of theſe Tracts, more fortunate in that reſpect in his Tranſlation, than in his Original, will (if living) rejoice to ſee his Performance honour'd with the Eminent Names of the Duke of *Argyle* and Your Lordſhip.

I have no Plea, as a Stranger, for this Addreſs, but the Aptneſs of the Subject, which I hope will excuſe, both to Your Lordſhip, and the World, this Preſumption of,

My Lord,

Your Lordſhip's

Moſt Obedient, and

Moſt Humble Servant,

William Webſter.

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THE

USE *of the* GLOBES.

A Sphere or Globe is a round ſolid body, upon the ſurface whereof are drawn certain circles and figures, repreſenting the movement and diſpoſition of the heavenly bodies; or the ſituation and extent of the earth and water.

There are three ſorts of ſpheres.

1. The Cœleſtial, for the ſtars, *&c.*
2. The Terreſtrial, for the earth and ſeas.
3. The Armillary, which has reſpect both to the one and other.

N. B. *To make what follows the more intelligible, the Reader ſhould have an Armillary Sphere before him.*

Suppoſitions and Definitions.

1. The heavens appear like the concave ſurface of a globe, whoſe center is the middle of the

earth; and which continually turning round upon two of its points diametrically oppoſite to each other, carries about with it the ſtars and planets, which ſeem fix'd therein; making them every day deſcribe circles, which have the ſaid points for their poles.

2. The two points upon which the heavens thus turn, are called, *The Poles of the World.* That which is viſible to us in *Europe*, is the north, or artick pole; the other the ſouth, or antartick: The ſtraight line paſſing from the one pole to the other, is called, *The Axis of the World.* And the circles which the ſtars every day ſeem to deſcribe, are named, *The Parallels* of each ſtar. Every fifteen degrees of theſe circles, make an hour of time.

3. Some of theſe heavenly bodies ſenſibly change their places in the heavens, and thoſe we call *Planets.* And the circle which theſe ſtars deſcribe by their particular movement in thus changing their places, is called, *The Ecliptick.* Thoſe ſtars which do not ſenſibly change their places in the heavens, are called *Fixed Stars.* For the better recollection of the ſeveral fixed ſtars, they are reduced to certain figures, called *Conſtellations*; the twelve principal of which, are thoſe which give names to the twelve diviſions of the ecliptick, and are called, *The twelve Signs of the Zodiack.*

4. A body is ſaid to deſcend, when it approaches towards the center of the earth; but when it recedes from it, and becomes more diſtant, it is ſaid to aſcend. A line is ſaid to be plumb or right to the earth, when being prolonged it would paſs

through its center as AC. A line is ſaid to be horizontal, when it is perpendicular to ſuch a plumb or right line as DE; and when a line makes an acute angle with a plumb line as CF, it is then ſaid to be inclined. *Fig.* 1.

5. In whatever place of the earth we are, we may ſenſibly perceive one half of the heavens; and may eaſily imagine a circle dividing that part which we ſee, from the other which we do not ſee; and ſuch circle is called, *The Horizon*; the middle point of the viſible part of the heavens (which is directly over our heads) is called, *The Zenith*; and the middle point of the inviſible part (which is directly under our feet) is called, *The Nadir*: And as theſe two points anſwer in every place to a line plumb or perpendicular to the earth, there are therefore as many different zeniths and nadirs, and conſequently horizons as there are different points upon the earth. For example, if I ſtand at the point A, my zenith will be the point in the heavens C, my nadir F, and my horizon the circle BD. But if I am at the point K, my horizon will be HI, my zenith G, and my nadir L. *Fig.* 2.

6. We call it *Day*, when the ſun is in that part of the heavens which we ſee; but when it is in the other part inviſible to us, we call it *Night*. In the ſame manner we call that part of the parallel which is deſcribed by any ſtar in the viſible part of the heavens, its *diurnal Arch*; the remaining part of the parallel is called its *nocturnal Arch*. That little glimmering of light which appears before or after day, we call the *Twilight* or *Crepuſcle*.

PROP. I.

Of the Armillary Sphere.

1. An Armillary ſphere is compoſed of ten open circles, with a little ball or button in the middle, anſwering to the center of the earth, ſupported by a ſmall wire repreſenting the axis of the world. *Fig.* 3.

2. There are ſix great circles, and four ſmall ones; the great ones are, the Horizon, the Meridian, the Equator, the Zodiack, and the two Colures.

HORIZON.

The Horizon is a great circle, dividing that part of the heavens viſible to us, from the other part which we do not ſee. But there being as many different horizons as there are different places, the horizon of the ſphere is therefore made moveable*. This circle is divided into 32 equal parts, anſwerable to the 32 points of the mariner's compaſs, the 4 chief of which are the north, or that point of the horizon anſwering to the north-pole; the ſouth, anſwering to the ſouth-pole; the eaſt, or that point of the horizon where the ſun riſes, when the days and nights are equal; and the weſt, which *Fig.* 4.

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* Or rather, it ſhould be ſaid, the ſphere is contriv'd to turn within this circle. The ſame thing is to be underſtood in the next paragraph, with regard to the meridian.

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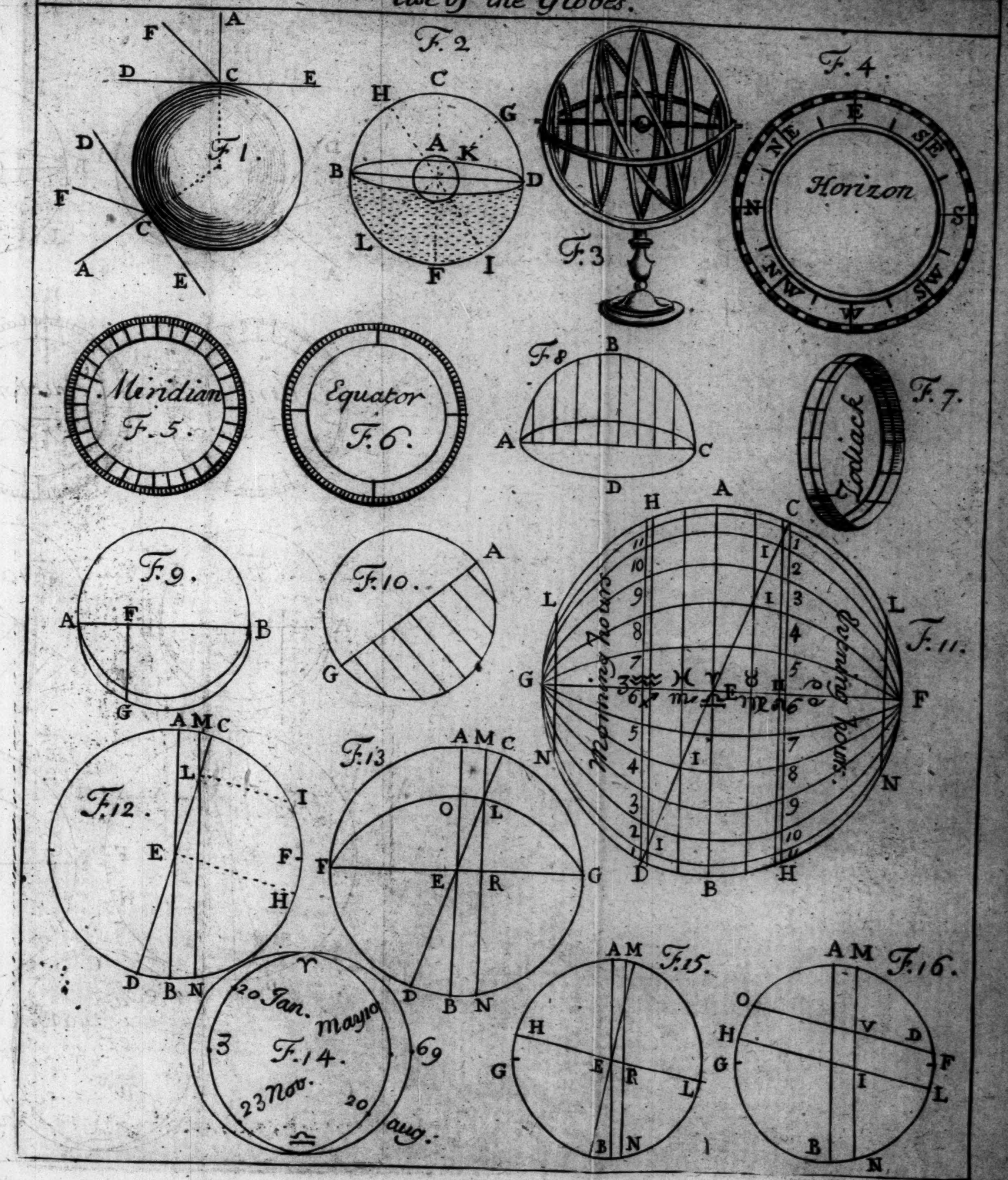
Use of the Globes.



which is that point where the ſun ſets when the days and nights are equal. The middle points betwixt any two of theſe principal ones, take their names from thoſe two they are between, as the north-eaſt is the middle point between the north and eaſt. The ſame is alſo to be underſtood of the other diviſions, for we call that point the north-north-eaſt which is between the north and the north-eaſt, *&c.* And thus names are given to the 32 points of the horizon. The horizon is again divided into 360 degrees, which laſt diviſion is alſo applied to the three following circles of the ſphere. The horizon ſerves to ſhew the riſing and ſetting of the heavenly bodies, the length of the days and nights, and the courſe of the winds, or points of the compaſs.

MERIDIAN.

The Meridian is a great circle paſſing thro' the two poles of the world, and through the zenith and nadir points of each country. *Fig.* 5. It is made moveable in the ſphere, to the end it may repreſent the different meridians of the ſeveral countries. This circle chiefly ſerves, 1. To divide the diurnal and nocturnal arches into two equal parts, ſo that when the ſun is in the meridian, it is then mid-day or mid-night. 2. To mark the meridian height of the ſtars, which is an arch of the ſaid circle, comprehended between the ſtar and the horizon. 3. To ſhew the latitude of every country, which is that arch of the meridian comprehended between the horizon of the country and the pole; or that arch of the ſaid circle included betwixt the zenith of the place and the equator; of which we now proceed to ſpeak.

EQUATOR.

The Equator is a great circle equally diſtant from the two poles of the world. It has divers uſes, 1. When the ſun is in the equator the days and nights are equal every where, except under the poles. 2. The equator is the boundary from whence we begin to meaſure the latitude of places, and the declination of the heavenly bodies: For as the latitude of a country is that arch of the meridian contain'd between the equator and the zenith of the place; ſo the declination of a ſtar is alſo that arch of the meridian included between the equator and the ſtar. If the zenith of a country is between the equator and the north-pole, its latitude is north; but if between the ſouth-pole and the equator, its latitude is ſouth; the ſame is to be underſtood of declination. 3. On the equator is reckon'd the longitude of places, and the right aſcenſion of the heavenly bodies: For the longitude of a country is the arch of the equator between the meridian of ſuch place, and the place through which the firſt meridian is accounted to paſs (which with us is *London*, or the pike of *Teneriff*, and with the *French* the iſle *de Fer)* and the right aſcenſion of a ſtar is alſo the arch of the equator, between the firſt degree of *Aries*, and the meridian paſſing through the ſaid ſtar.

Fig. 6.

Note, Both longitude and right aſcenſion are reckoned from weſt to eaſt. 4. The circles daily deſcribed by the heavenly bodies, being apparently parallel to the equator, time is therefore meaſured by the degrees of the equator, 15 of which are equal to an hour, and conſequently the whole 360 to 24 hours.

ZODIACK.

Fig. 7.

The Zodiack is a broad circle 16 degrees wide, through the middle of which runs the ecliptick of the ſun, or that great circle which the ſun deſcribes yearly, as it changes its place in the heavens; by its particular movement. The ecliptick cuts the equator in two points, called the *Equinoxes*, making therewith an angle of 23° 29′ which is the greateſt declination of the ſun. The ecliptick and zodiack are divided into 12 equal parts, called *Signs*; beginning from the firſt equinoctial point, or firſt degree of *Aries*, and proceeding from weſt to eaſt. They have the names and figures following, *viz.* *Aries* ♈, *Taurus* ♉, *Gemini* ♊, *Cancer* ♋, *Leo* ♌, *Virgo* ♍, *Libra* ♎, *Scorpio* ♏, *Sagittarius* ♐, *Capricornus* ♑, *Aquarius* ♒, *Piſces* ♓. The particular day of each month upon which the ſun enters each ſign, is alſo added: Laſtly, each ſign is divided into 30 degrees, and the ſun running through very near a degree every day from weſt to eaſt, is a little more than 365 days in paſſing through the whole ecliptick.

COLURES.

The colures are two particular meridians, one of which paſſing through the equinoctial points of the ecliptick, is called the *Equinoctial Colure*: The other, paſſing through the two points of the ecliptick, which are fartheſt diſtant from the equator, is called the *Solſticial Colure*. They cut the equator into 4 equal parts, which make the 4 ſeaſons, *viz.* 1. The ſpring, or that part of the ecliptick between the firſt point of *Aries* and the laſt of *Gemini.* 2. The ſummer, or that part of the ecliptick between the laſt point of *Gemini* and the firſt of *Libra.* 3. The autumn, or that part of the ecliptick between the firſt point of *Libra* and the laſt of *Sagittarius.* 4. The winter, or that part of the ecliptick between the laſt point of *Sagittarius* and the firſt of *Aries.*

3. There are alſo 4 leſſer circles, *viz.* the two tropicks, and the two polar circles. The tropicks are the ſun's moſt diſtant parallels from the equator; that toward the north is called the *Tropick of Cancer*; and that toward the ſouth, the *Tropick of Capricorn.* The polar circles are alſo parallel to the equator, and paſs through the poles of the ecliptick; one is called the *Artick*, or *North polar Circle*; the other *Antartick*, or *South polar Circle.*

PROP. II.

Of the Cœleſtial Globe.

1. The Cœleſtial ſphere is furniſhed with the ſeveral circles before deſcribed, *viz.* the horizon, meridian, equator, the ecliptick of the ſun, the two colures, the tropicks, and the polar circles.

2. Through the poles of the world and the diviſions of the equator, are drawn circles at every 10 or 15 degrees, which are called *Circles of Right Aſcenſion.* And through the diviſions of the meridian, at every 10 degrees, are alſo drawn circles

parallel to the equator, called *Circles of Declination.*

3. In the ſame manner, through the diviſions, and through the poles of the ecliptick at every 10 degrees, are alſo drawn circles, to which we give the name of *Circles of Aſtronomical Longitude:* And laſtly, through the diviſions of the ſolſtitial colure at every 10 degrees, are drawn circles parallel to the ecliptick, and called *Circles of Aſtronomical Latitude.*

4. Every ſtar is placed in the interſection of its right aſcenſion and its declination; for example, to find the bright ſtar of *Aries*, whoſe right aſcenſion is 27° 35′ and its declination 22° 1′ N. place the moveable meridian upon 27° 35′ of the equator, and that point of the globe anſwering to 22° 1′ of the meridian, betwixt the equator and the north pole, is the place of the ſaid ſtar; and ſo of all the reſt.

PROP. III.

Of the Terreſtrial Globe.

1. The terreſtrial globe is alſo provided with a moveable horizon and meridian; and the equator, ecliptick, the tropicks, and the polar circles, in like manner too at every 10 degrees, circles are drawn parallel to the equator, which are called *Parallels of Latitude*; and alſo through the poles, and through every 10 degrees of the equator, other circles which are called *Circles of Longitude.*

Note, *Theſe circles of longitude are more commonly drawn through every* 15 *degrees of the equator.*

2. Every country is laid down in the interſection of its proper longitude and latitude. Thus to find the pike of *Teneriff*, whoſe longitude (if the firſt meridian be ſuppoſed to paſs through *London*) is 26° 31′, and its latitude 38° 32′, bring the moveable meridian to 26° 31′ of the equator, and counting on the meridian from the equator northwards 38° 32′ under that point will be found the pike of *Teneriff*. Or, if *London* were the place you look for, whoſe longitude is 0′ and latitude 51° 32′ bring the moveable meridian to the firſt point of the equator, and 51° 32′ on the meridian gives you the place of *London* on the globe. Thus knowing the longitude and latitude, any place on the globe may be eaſily found. Hereafter the manner of finding both the one and the other ſhall be ſhewn.

3. The terreſtrial globe may be placed in three different ſituations. 1. If the equator is perpendicular to the horizon, we call it a right ſphere. 2. If the equator is inclined to the horizon, we call it an oblique ſphere. 3. If the equator is parallel to the horizon, we call it a parallel ſphere. The people who live under the line, that is, who have their zenith in the equator, have their ſphere right: Thoſe that dwell under either of the poles (if there be inhabitants there) have their ſphere parallel. All the reſt of the world have their ſphere oblique.

4. When the ſphere is right the horizon cuts all the parallels of the ſun's declination into two equal parts, and conſequently the days are all equal to the nights. But when the ſphere is oblique, the horizon cuts thoſe parallels into two unequal parts, and therefore the days are longer than the nights in ſummer, and ſhorter in winter. Whereas the ſphere being parallel, the horizon does not cut the parallels, but one half being above, and the other half below, cauſes ſix months day, and ſix months night, to thoſe who have the ſphere in ſuch a ſituation.

5. Under the equator the longeſt days are but 12 hours, and the farther diſtant we go from it, the longer their days are in ſummer, ſo that under the polar circles the longeſt day is 24 hours, and approaching ſtill nearer to the poles, we find one month, two months, three months of day-light, till at the poles themſelves they come to ſix months.

6. The 4 leſſer circles of the ſphere divide it into five parts, called *Zones*, viz. two frigid, which are between the poles and the polar circles; two temperate, between the polar circles and the tropicks; and one torrid, betwixt the two tropicks.

7. The northern and ſouthern hemiſpheres are each divided into 30 climates. We call a climate ſuch a portion of the globe lying between two parallels of latitude, as has a month of day-light more than another, in the two frigid zones; or half an hour in the other zones. There are therefore

fore 24 climates betwixt the equator and either of the polar circles; becauſe there are 12 hours of day-light difference: And there are 6 climates betwixt each of the polar circles and its pole, becauſe there are 6 months of day-light difference.

8. There is annexed to the globe, a moveable quadrant, called, *The Quadrant of Altitude*, to repreſent the azimuths, and the almicantures. The azimuths are great circles paſſing through the diviſions and poles of the horizon. The almicantures are circles parallel to the horizon. The uſe both of the one and the other ſhall be ſhewn farther on.

PROP. IV.

Of the Uſe of the Sphere.

Since the intelligent reader will eaſily of himſelf diſcover the moſt part of the uſes of the ſphere; I ſhall here only ſet down a few, which may ſerve to open the way for the reſt.

To render the problems on the globes the more eaſy, on one of the poles is placed a circle, divided into 24 hours, with an index fixed upon the end of the axis; ſo that in turning about the globe, the index will paſs over all the hours.

1. Set the globe to the elevation of the country you are in, that is, raiſe the pole according to the latitude of the place, counting the degrees on the braſs meridian from the pole to the horizon.

2. Obſerve upon the eclíptick the ſun's place, and bring it under the meridian. Then will that

point of the ecliptick ſhew upon the meridian the declination of the ſun; and the meridian will ſhew upon the equator its right aſcenſion. Before you move the globe for the following operations, ſet the index of the hour circle to the upper 12.

3. Bring the ſun's place in the ecliptick to the eaſt part of the horizon, and the index of the hour circle will ſhew the hour of the ſun's riſing for that day; then moving the ſaid point of the ecliptick to the weſtern part of the horizon, the index will point to the hour of the ſun's ſetting.

4. Having taken the heighth of the ſun before noon, and fixed the quadrant of altitude on the zenith point; bring the ſun's place in the ecliptick to coincide with the quadrant of altitude, on the eaſtern ſide of the globe, then will the index ſhew the hour of the day, and the quadrant will mark the ſun's azimuth on the horizon. The ſame may be done on the weſt ſide of the globe for the afternoon.

5. Having found the azimuth of the ſun with a compaſs, there fix the quadrant of altitude, and bringing the ſun's place in the ecliptick to the quadrant, the ſame point of the ecliptick will ſhew the ſun's height on the quadrant, and the index will ſhew the hour.

6. The ſame things may be done with the other heavenly bodies, whoſe places you know, and many other curioſities; as to determine the whole ſituation of the heavens for any given time, the riſing and ſetting of all the ſtars, *&c.*

PROP.

Prop. V.

Of the Sphere in Plano.

1. The orthographic projection of the ſphere in plano is the ſhadow of the ſeveral circles of an armillary ſphere upon the plane of the meridian, made by rays perpendicular to that plane.

2. It is evident that if the circle ADC be enlightned with rays perpendicular to it, *Fig.* 8. the ſhadow of any other circle as ABC, perpendicular to it will be their common ſection AC. From whence it follows, that in the ſphere in plano, all the circles which are perpendicular to the meridian are projected into right lines: Thus the equator, ecliptick, horizon, and all the circles parallel to theſe are right lines upon the plane of the meridian.

3. It is alſo evident, that each point of the ſhadow AC, anſwers to each point of *Fig.* 8. the circle ABC by a perpendicular line AC. From whence it follows, that to know the number of degrees between the point A and the point F of the ſhadow of a *Fig.* 9. circle AB, the ſemi-circle AGB, muſt be deſcribed upon AB, and the perpendicular FG be drawn, ſo will the arch AG give the degrees of its ſhadow AF.

4. In the ſame manner, to divide the ſhadow of a circle AG into equal parts, draw *Fig.* 10. over it a ſemi-circle, and dividing it into equal parts, from every diviſion let fall perpendiculars upon AG.

5. The other circles of the globe muſt be expreſſed by ellipſes; but I forbear to demonſtrate that here, becauſe it is not neceſſary to the following problems, which are ſufficient for our preſent deſign.

PROBLEM I.

To project the Sphere in Plano.

Prepare the meridian AGBF with its diviſions and let the points GF be the poles of the world; the line AB will be the *Fig.* 11. equator, and making the arch AC 23° 29′, CED will be the ecliptick. CH, DH, will be the tropicks, and LN the polar circles; ſuppoſing FL and GL each 23° 29′. Farther, having divided the ecliptick DEC into 6 parts, of which each muſt be 30°; draw through the points of the diviſions the lines parallel to the equator, which will repreſent the ſigns. Laſtly, divide the equator AEB into 12 parts, each of which muſt be 15°, and through each point of the diviſions, and the two poles, draw the ſeveral ellipſes, and you will have the hour-circles GNF. There ſhould alſo be placed on the center E, a moveable ruler to repreſent the horizon, divided as above deſcribed; there ſhould alſo be another little ruler, ſo placed upon this, as always to ſtand perpendicular to it. The figure will make all plain. The uſe of this ſphere is too eaſy, to require farther explanation. It is ſufficient to know, that it ſerves to find the amplitudes, the declination, the hour, the right aſcenſion and azimuth of the ſun, as we are going to explain it in a manner the moſt univerſal, and which does not require the apparatus of an aſtrolabe, rulers, and other machines, too troubleſome for carriage.

PROBLEM II.

To deſcribe upon the Sphere in Plano, the Parallels of a Day given.

Having determined AB to repreſent the equator, and CD the ecliptick; draw EH perpendicular to the ecliptick CD, and the point H will be the place of the ſun on the 20th of *March* N. S. Take then from H upwards towards C, as many times 30 degrees as there are months paſt, from the 20th of *March* to the day given; and alſo as many degrees as there are days above the months, and you will have the point of the ecliptick anſwering to the day given: For example, ſuppoſe the 23d of *May* was the day given, take 63 degrees from H to I, which will be the place of the ſun on the 23d of *May*: From the point I draw IL perpendicular to the ecliptick CD, and through the point L, draw MN parallel to the equator, and you have the parallel of the given day; that is to ſay, the ſhadow of the circle which the ſun will deſcribe that day.

Fig. 12.

Note, For greater exactneſs, you may obſerve the day the ſun enters into each ſign, and count a degree for each day only therefrom.

PROBLEM III.

To find the Declination of the Sun.

Having laid down the parallel of the day MN, meaſure with a graduated ſemi-circle, the arch A M, or the angle A E M, *Fig.* 12. which is the ſun's declination for the day given.

PROBLEM IV.

To find the Right Aſcenſion of the Sun.

After having found the point L for the given day; the ellipſis FLG will cut the equator in the point O, and OE will *Fig.* 13. be the diſtance of the ſun at its neareſt approach to the equinox E; and as LR contains the ſame number of degrees as OE, you muſt find the number of degrees in LR (See *Fig.* 9.) to have the diſtance of the ſun at its neareſt approach to the equinox, which will be the right aſcenſion of the ſun during the ſpring, and its ſupplement during the ſummer; but during the autumn, you muſt add 180, and ſubtract it from 360 during the winter, to find the ſun's right *Fig.* 14. aſcenſion, as is plain from *Fig.* 14.

PROBLEM V.

To find the Point of the Horizon where the Sun at riſing or ſetting will be, at any Day or Place given.

Fig. 15. After having found the parallel MN, for the given day; take AH the complement of the latitude of the place, and the line HEL will be the horizon of the place; whoſe interſection with the parallel at the point R will be the point ſought. The degrees between R and E will be the diſtance of the ſun from the true eaſt or weſt points of the world. This diſtance is called the eaſtern amplitude, with regard to the riſing; and the weſtern amplitude, with regard to the ſetting of the ſun.

PROBLEM VI.

To find the Hour of the Sun's riſing and ſetting.

In the foregoing figure the line RN will give the degrees of the parallel which the ſun has run through from midnight at N, to its riſing at R. In the ſame manner the line MR will give the degrees the ſun has run through from its midday point M, to its ſetting at R. Divide then the number of thoſe degrees by 15, and you have the hours from midnight to the ſun's riſing, and from noon to its ſetting.

PROBLEM VII.

The Heighth of the Sun being given, to find the Hour and Azimuth of the Place given.

Reſume the foregoing figure, and add to it the line OD parallel to the horizon HL, ſo that the arches HO and LD, will be the height of the ſun: Then will OD be the almicanture of the ſun, and cutting the parallel of the ſun in the point V, will give VN for the hours ſince midnight; VM for the hours ſince noon. In the ſame manner VO will give the degrees of the almicanture between the ſun and the meridian, or the angle of the ſun's azimuth with the meridian.

Fig. 16.

REMARK.

A very little reflection upon what has been laid down, will render the demonſtration eaſy; and help to find out many other ſuch like problems, by which may be diſcovered a general method of reſolving ſpherical triangles, with only a ruler, a pair of compaſſes, and a protractor.

NAVI-

NAVIGATION.

NAVIGATION is a ſcience, by which we learn to conduct a ſhip upon the ſea with eaſe and ſafety.

We ſay nothing of the terms * ſince the perſons for whom this work is intended, will learn them much eaſier from practice than by books.

PART I.

Of the Inſtruments uſeful in Navigation.

IT would be proper the reader ſhould have the inſtruments deſcribed, before him, when he reads what follows.

PROP.

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* Tho' the author (intending this part of his work only for the uſe of ſea-faring people) has given no explication of ſea-terms and phraſes, yet being deſirous to make the following Tracts intelligible to thoſe likewiſe who are unacquainted with the ſea-language; I have annexed to the tranſlation, an alphabetical explanation of the ſeveral terms and phraſes therein made uſe of, which I doubt not will be acceptable.

Prop. I.

Of Inſtruments for taking Heights with a plumb Line.

It has been already remark'd, that the height f a ſtar above the horizon, is an arch of a vertical r an azimuth circle, comprehended etween ſuch ſtar and the horizon. Thus he height of the ſtar A, above the horizon CB, is the arch AB, or the meaſure of the ngle ADB.

Fig. 1.

1. The height therefore of the ſtar A may be aken with a quadrant or ſemicircle divided into egrees: That is to ſay, having diſpos'd the inſtrunent in ſuch manner upon its foot, that the plumnet may play freely upon the limb, direct the ghts towards the ſtar A, and the plumb line will ive the height of the ſtar, or angle ADB.

2. In the ſame manner an aſtrolabe may be nade uſe of, which is a graduated ircle, whoſe diviſions begin from the oint D. It is to be ſuſpended by e point A, then will the weight B keep the ne AB vertical, and the line CD horizontal. pon the center E, a moveable ruler with wo ſights is contrived to turn, which being dicted to the ſtar H, the angle GED gives its eight.

Fig. 2.

3. The ring AB is ſtill a better inument; becauſe its diviſions are more ſtinguiſhable. There is a hole pierc'd

Fig. 3.

thro' in the point C, and as it is ſuſpended by the point A, the weight B renders the line AB and its parallel CD vertical, and the line CE horizontal. Thus when the ray of the ſun F, paſſes through the hole C, it falls upon the point G, and the angle GCE gives the ſun's height. The whole artifice conſiſts in dividing the ſemicircle EGD into 90 degrees, beginning at the point E.

Theſe kinds of inſtruments are not ſo fit for ſervice at ſea, by reaſon the motion of the ſhip will not permit the plumb-line to ſettle.

PROP. II.

Of the Fore-Staff.

1. The Fore-ſtaff uſed at ſea, is compoſed of three pieces, *viz.* a croſs-piece or vane DC, a moveable ſight EF, and a ſtrait quadrangular piece, or the ſtaff itſelf BA, upon which the vane is made to ſlide, and ſo exactly fitted, as that it may always ſtand at right angles with it. *Fig.* 4.

2. The moſt uſual way of taking the ſun's height with this inſtrument, is thus; place the vane CD at the end B of the ſtaff, then applying the eye to the end C of the vane, and turning the back to the ſun, move the ſight-vane EF backwards and forwards till the ſhadow of the end D falls exactly upon the ſight EF, at the ſame time that the eye at C ſees the extremity of the horizon acroſs the ſame ſight EF: For then the

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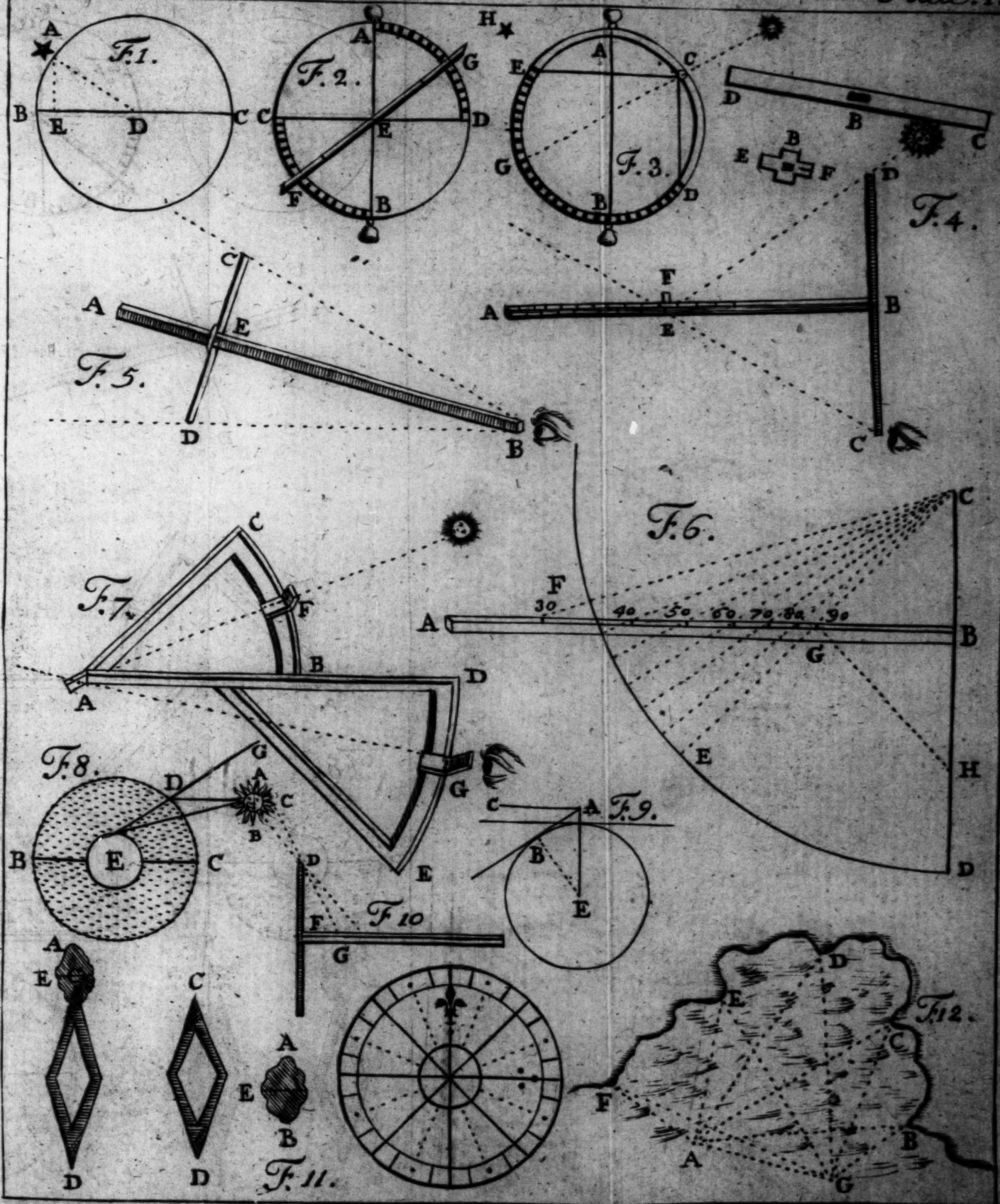

the line CE is horizontal, and the angle DEC the height of the ſun above the horizon; this angle is marked upon the ſtaff at the point E, where the ſight-vane is brought.

3. Another method is uſed, to take the height of ſtars which give no ſenſible ſhadow. Placing the eye at the point B of the ſtaff, move the vane CD backwards and forwards, till the eye at B at once ſees the ſtar it is obſerving by the end of the vane C, and the horizon by the other end D; for then will the line BD be horizontal, and the angle DBC will be the ſtar's height above the horizon. *Fig.* 5.

REMARK.

In both ways the part EB of the ſtaff, is the tangent of the angle BCE, the complement of CBE in *Fig.* 5. and of CEB in *Fig.* 4. which is the half of the angle CBD, or CED the angle of the height found: Therefore the ſame diviſions of the ſtaff ſerve in both caſes.

4. The ſtaff BA is thus divided: Draw the perpendicular BC, equal to one half of the vane; then from the point C, deſcribe a quadrant DF, and having ſet off 45 degrees from D to E, draw CE, which will cut the ſtaff BA in the point G, and ſo give the diviſion of 90 degrees, ſince BG will be the tangent of 45 degrees, the complement of the half of 90 degrees. In the ſame manner divide the half quadrant EF into 90 parts, and from the point C, drawing lines to the ſaid diviſions, your ſtaff will be divided into degrees; for in proportion *Fig.* 6.

portion as the angle GCB is augmented half a degree, the angle CGH will be diminiſhed a whole degree.

The ſame method is to be purſued to lay down the minutes, every 10 of which ſhould be diſtinguiſhed, or, if practicable, every 5.

5. It would be ſtill much more eaſy to divide the ſtaff BA, by means of a ſcale, of the length of half the vane, divided into a thouſand equal parts, and a table of tangents, whoſe ſign total muſt be but 1000 parts: For taking from the ſcale ſo many parts as are found contained in the tangent of 45 degrees, and laying them down upon the ſtaff from B to G, you have your firſt diviſion of 90 degrees. In the ſame manner, taking from the ſcale the number of parts contained in the tangent of 45 degrees 30′, and ſetting them upon the ſtaff from the point B, you have the ſecond diviſion of 89 degrees, &c. Do the ſame for the minutes.

REMARK.

If the vane is ſmall, the diviſions will ſtand too cloſe, and if large, many of them will fall beyond the length of the ſtaff: They have therefore commonly four vanes, the leaſt of which ſerves for the ſight-vane, and gives almoſt all the diviſions. Each vane is adapted to one particular ſide of the ſtaff, to which the diviſions thereon agree; and as the half of each vane anſwers to the diviſion of 90 degrees upon its correſpondent ſide, they are eaſily diſtinguiſhed.

PROP.

Prop. III.

Of the Engliſh Quadrant.

1. The *Engliſh* quadrant is composed of the ſtaff AD, and two arches of a circle, both which have the point A for their center, *viz.* BC, DE; theſe two arches together make up a quadrant; the diviſions upon BC are of 5 degrees each, but upon DE not only every ſingle degree is mark'd, but even every two minutes: There are three ſights or vanes, all perpendicular to the plane of the inſtrument; the firſt is fixed at the point A, the two others run one upon the arch BC, and the other upon DE. *Fig.* 7.

2. To uſe this inſtrument, they firſt fix the vane F, and then raiſe or fall the vane G, till the ſhadow of the vane F falling upon the vane A, he eye being applied to the vane G, ſees the horizon a-croſs the ſame vane A: For then is the line GA horizontal, and the angle FAG is the height of the ſun.

It will be eaſy to apply this inſtrument to the tars, nor will the Reader find much difficulty in diſcovering by himſelf the other uſes of the quadrant, and of the other inſtruments which differ but very little from it.

Prop. IV.

Errors to be corrected in taking Heights.

1. I ſay nothing here concerning the parallax of the ſun, which is not determinable by any intruments now in uſe.

2. The firſt error common to heights, is occaſion'd by refraction, which makes a ſtar, &c. appear more elevated than its true height: As ſuppoſing A the ſun, E the eye, and BC the horizon, the true height of the ſun will be AEC; but becauſe the ray AD entering into the vapours of the earth, or more truly the atmoſphere, is broke in the point D, and paſſes to the eye E, thro' the line DE, the ſun will ſeem to be in the line EDG, and its apparent height will be DEC, therefore the angle AEG muſt be ſubtracted, to have the true height AEC. The angle AEG is greateſt, when the ſtar, *&c.* has the leaſt altitude, as may be ſeen in the following table, wherein is ſet down, what ought to be deducted from the apparent height, to obtain the true.

Fig. 8.

Apparent Heights *Degrees*	Refractions *Minutes*
0	31
1	23
5	11
10	7
20	1

But according to Sir *Iſaac Newton's* table ſince publiſhed, the refractions are found ſomething different; for the curvature of the ray between D and E cannot be mathematically determined, as the ray is not ſuddenly broke or bent at D, as ſhewn in the figure, but only begins there to bend, and increaſes bending more and more continually, 'till it arrives at E, where the denſity of the atmoſphere is the greateſt; wherefore this editor hath added a part of his table, as followeth:

Heights *Degrees*	Refractions *Min.*	*Sec.*	Heights *Degrees*	Refractions *Min.*	*Sec.*
0	33	45	20	2	26
1	27	7	25	1	54
2	17	8	30	1	32
3	13	20	40	1	4
4	10	48	50	0	45
5	9	2	60	0	31
10	4	52	70	0	20
15	3	17	80	0	10

3. The ſecond error regards the obſervation of the horizon at ſea; and it proceeds from that the eye of the perſon making the obſervation, being raiſed above the ſurface of the ſea, ſees the bounds of the horizon by the tangent AB, which differs from the horizontal line AC, by the angle BAC. It would be eaſy to make a table of this error, with regard to the different elevation of the eye: For as EA, the ſum of the radius of the earth and elevation of the eye, is to the ſine total; ſo is the radius of the earth to the ſine complement of the error BAC. But care muſt be taken, that if the height is obſerved with the eye directed to the object, the error of the height found be ſubtracted; but if the obſervation is made with the back turn'd thereto, the error is then to be added.

Fig. 9.

4. The error ariſing from the not piercing the ſights of inſtruments, is ſtill more conſiderable; for ſuch ſights give only the upper limb of the ſun, and conſequently

Fig. 10.

ſometimes give the height 15′ above the truth. For if the end D of the vane be obverted towards the ſun ACB, the ſhadow G will give the height of the limb A, and not that of the center C, which is ſometimes leſs by 15′.

Prob. V.

Of the Mariner's Compaſs.

1. There are two oppoſite points in a loadſtone, which are called its *Poles*; becauſe being ſuffered to move freely, whether ſuſpended by a thread, or floating upon cork in the water, it will turn one of theſe points towards the north pole, and the other towards the ſouth.

2. The ſtone communicates its virtue to iron. Having therefore a load-ſtone, whoſe north pole is A, and its ſouth pole B, prepare a thin plate of iron, hollow'd out in the middle, and rounded at the two ends, then apply the plate to the load-ſtone in ſuch manner, that the point C may be between the two poles at E, and conduct it ſoftly along the ſtone, till the point C touches the pole A; then will the plate have the virtue of turning its point C towards the north pole, and its point D towards the ſouth. *Fig.* 11.

3. Prepare a circle of paſte-board, having on one ſide laid down upon it the points of the compaſs, and to the other ſo faſten your iron plate, that the point C may exactly anſwer to the north point of the card, and the point D to the ſouth, then fixing in the center of the card, a hollow

cone

cone of braſs, and placing it upon a pivot, the card will play freely, and turn its north point towards the north pole of the world, and conſequently its ſeveral diviſions will mark out the whole courſe of the winds, each reſpecting its proper point.

I ſhall not detain the reader with the other parts of the compaſs, nor the manner of its uſe; neither do I think it needful to deſcribe the compaſs of variation, or azimuth compaſs, ſince I write for perſons to whom theſe things are very familiar.

4. I ſhall therefore only add, that the compaſs is neceſſary to take the plan of a place at ſea, becauſe of the motion of the veſſel. The manner of uſing it to that purpoſe, is as follows. Suppoſe, for example, it was required to take the plan of the road BCDEF. *Fig.* 12. At the point A, ſo place your compaſs, that through the ſights you may obſerve the point B, and mark the degrees of the card cut by one of the ſights; do the ſame for the point C, and the degrees found between the points B and C will be the meaſure of the angle BAC. In the ſame manner you may find the angles CAD, DAE, EAF, then from the point G, taking alſo the angles FGA, EGF, DGE, CGD, BGC, you have ſufficient *cognita* to form the plan of the road. See *Practical Geometry*, Prop. 4.

PROP. VI.

The declination or variation of the Compaſs.

The compaſs has very often a ſenſible declination, that is to ſay, its north point does not always anſwer exactly to the north pole of the world; but tends either towards the eaſt or weſt. We ſhould therefore be often deceived, if this declination, which frequently changes, were not exactly obſerved.

I ſhall only give the three ways of obſerving the variation (for ſo they term the declination of the compaſs) which are moſt eaſy, and moſt commonly uſed; but for the better underſtanding them, it would be convenient for the reader to have before him an azimuth compaſs.

1. When the lower limb of the ſun juſt appears above the horizon, ſet the compaſs of variation, ſo that the ſights may exactly reſpect the ſun's center, and obſerve the point of the compaſs which the ſights cut. If that point is the ſame whereon the ſun ought to riſe or ſet (which you may know by the amplitude of its riſing or ſetting) the compaſs has no variation: But if that point is farther from the north than the point whereon the ſun ought to be, the compaſs declines ſo many degrees, and on the ſame ſide with the ſun; if the ſaid point is leſs diſtant, the compaſs declines ſo many degrees towards the ſide oppoſite to the ſun, that is to ſay, N. E. in the evening, and N. W. in the morning.

2. At any hour of the day ſet the compaſs ſo that the ſhadow of a thread, joining the two ſights, may fall exactly upon the middle of the chapel (for ſo the braſs cone upon which the compaſs turns, is call'd) and obſerve how much the ſaid ſhadow deviates from the north point of the compaſs; then ſeeking by the azimuth the ſun's diſtance from the north at the time of the obſervation, if the two deviations are equal, there is no variation of the compaſs; but if they are unequal, the variation will be as above deſcribed.

3. When the pole-ſtar, and the third ſtar in the tail of the great bear (beginning with that at the end of the tail) may be cut by a plumb line: So ſet the compaſs of variation, that the ſame line which cuts the two ſtars, may alſo cut the two ſights of the compaſs, for then if the ſights of the compaſs fall exactly upon its north point, there is no declination; but if the ſights and north point do not anſwer each other, the difference will be the declination on the ſame ſide with the north point of the compaſs.

The demonſtration of theſe practices is very evident; as well as the manner of correcting the variation, or declination of the compaſs.

PROP. VII.

Of Sea Charts.

I ſhall ſay nothing of charts which ſome pretend to make, comprehending large parts or portions of the globe; which will by what follows, appear to be of very little uſe.

1. Thoſe charts wherein the circles of latitude and of longitude are laid down as parallels, and of equal diſtance, are of no worth (unleſs they only repreſent a ſmall ſpace, and that near the line) becauſe they give the ſame extent to a degree in thoſe parallels near the pole, as in thoſe ear the equator.

2. Charts of diſtance may be uſeful enough, if they are exactly made. They are begun by laying down the ſquare or oblong ABCD, and dividing the ſide AB, which ſerves as a parallel, into ſo many equal parts as there are leagues between the two moſt diſtant places towards the eaſt and weſt to be laid down in the chart; and the line AB ſo divided, will ſerve as a ſcale of leagues. Then having fixed upon ſome certain point as D, for ſome noted port, as *Toulon*, to lay drown another, as ſuppoſing *Cape Quiel*, draw the line DF upon that point of the compaſs, which the cape of *Quiel* bears from *Toulon*, and taking upon the ſcale ſo many leagues as is the diſtance between the places, lay it down from D upon the ſaid line to F, which ſhall be the point where cape *Quiel* is to be placed. The ſame thing is to be done for all the other places to be laid down in your chart.

Fig. 13.

There are two methods of trying the truth of this ſort of charts. 1. By obſerving if the places laid down anſwer to one another by their proper bearings; for example, after having laid down *Marſeilles* and *Majorca*, ſee if they anſwer each other according to the points of the compaſs they ought to lie upon. 2. By obſerving if the places which ſhould have the ſame latitude, fall in the ſame

Navigation. Plate 2.

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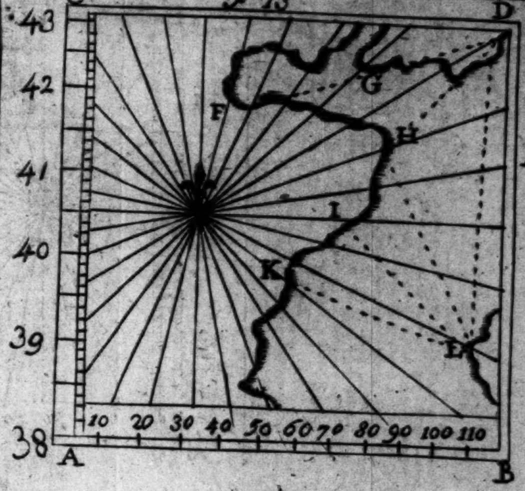

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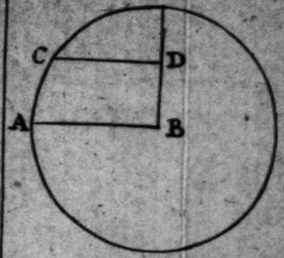

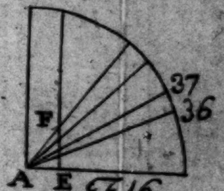

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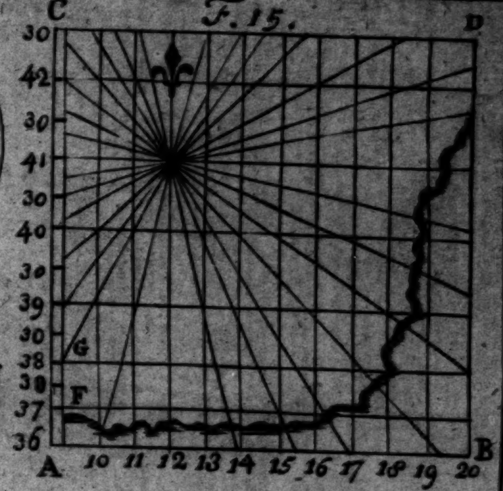

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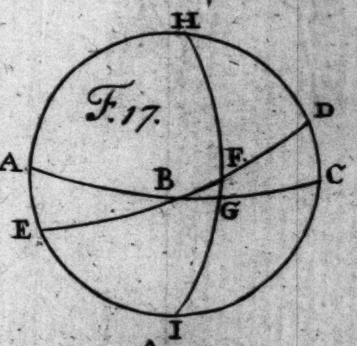

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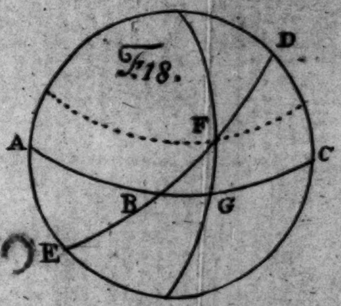

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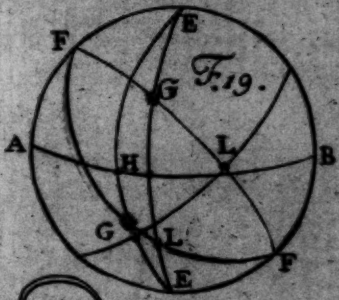

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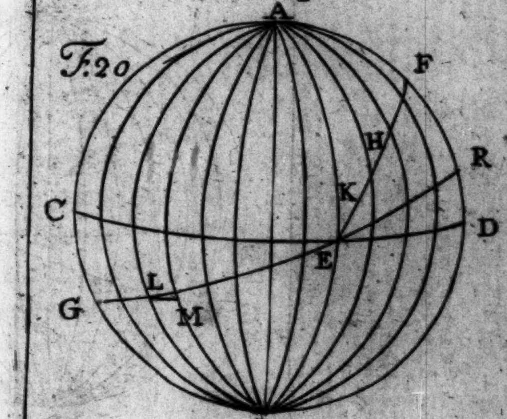

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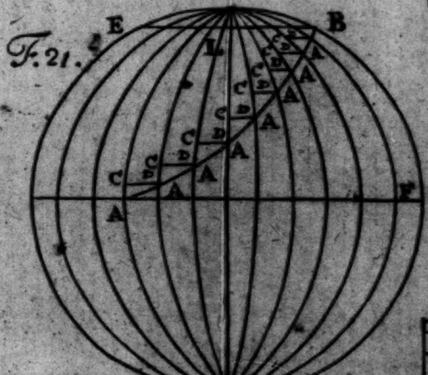

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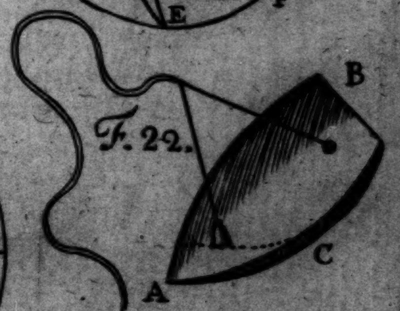
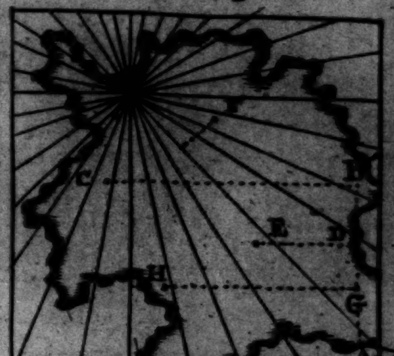
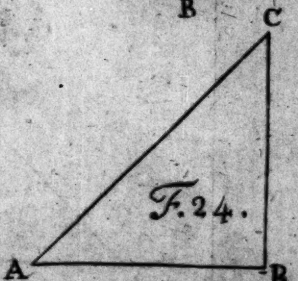
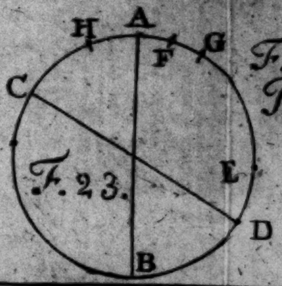


F 26





F.24.



F.23.

F.25. Vide Plate. 3.

ſame line, parallel to AB. The latitude may be laid down upon theſe charts, and from the latitude, or two different bearings, the diſtance of places may be determined.

It is farther to be obſerved, that to render this ſort of chart truly ſerviceable, they muſt include but a ſmall ſpace, and that not near the poles, eſpecially if the latitude be laid down in equal parts taken from the line AC.

4. * Reduced charts are the beſt ſort, the conſtruction of which will appear in the following remarks.

REMARKS.

In ſea charts, the meridians ought to be parallel, that the points of the compaſs may bear in ſtraight lines; but then this paralleliſm will occaſion a conſiderable error in making the degrees of all the parallels equal, and laying down, for example, 20 leagues in a degree in the parallel of 60, which ought to have but 10.

To remedy this error, the degrees of latitude ought to be enlarged in the ſame ratio, as the degrees of longitude are diminiſhed, and the degrees of latitude will ſerve as a ſcale in ſuch ſort, that the ſcale increaſing in proportion, as we approach the pole, the degrees of longitude, which have all the ſame length, will contain fewer leagues in proportion as they approach the pole.

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* What the *French* call *Reduc'd Charts*, are the ſame which with us go by the name of *Mercator Charts*.

To find the ratio between the degrees of latitude and longitude, obſerve that if AB be *Fig.* 14. taken for the radius of the equator, and CD for the radius of a circle parallel to the equator; the degrees of the equator will be to the degrees of the parallel, as the radius AB to the radius CD, (by the 1. 12. of *Euclid)* or as the ſine total to the ſine complement of the arch AC; and as the ſine total is a mean proportional between the ſine complement and the ſecant (by the laſt Prop. of *Trig.)* we conclude that the degrees of the equator, or of the latitude, are to the degrees of the parallel, or of the longitude, as the ſecant to the ſine total. Thus taking the degrees of longitude always equal for the ſine total, the degrees of latitude muſt conſequently encreaſe as the ſecants of the latitudes.

5. Having prepared the rectangle *Fig.* 15. ABCD, and divided its ſide AB into ſo many equal parts as you would have degrees of longitude in your chart: Draw through the diviſions, lines parallel to the ſide AC, which will repreſent the meridians: Then having fixed the latitude where you would have your chart begin, and laid it down on the line AC, for example, 36 degrees north: make AF one degree of longitude, the radius of a circle, from *Fig.* 16. whence take the ſecant of 37 degrees for the line AF, and the ſecant of 38 degrees for FG, *&c.* and thus you will have the ſide AC divided into increaſing latitudes. Through theſe diviſions draw lines parallel to AB, and they ſhall repreſent the circles of latitude. After which it will be no difficult matter to lay down each place in the interſection of its reſpective lon-

gitude and latitude; and to add a compaſs to your chart.

A ſcale of increaſing latitudes, may be ſtill more exactly made with a rule of 1000 equal parts, to one degree of longitude; to lay down every 10 minutes, it will be ſufficient to divide each degree into ſix equal parts. But to perform the thing in the moſt exact manner, by the help of tables and ſuch ſcale of 1000 parts: From the ſixth part of a degree, ſubtract ſo many parts as the ſecant of a degree, and 10′ is leſs than the ſecant of a degree and 60′, and the remainder will be the firſt part, or the firſt 10 minutes; and by adding them, you will obtain the laſt part: in the ſame manner ſubtracting from the ſixth part of a degree, ſo many parts as the ſecant of a degree and 20′ is leſs than the ſecant of a degree and 50′, the remainder will give the ſecond part, and adding the ſame, you will get the fifth part. All which is clear.

PROP. VIII.

Of Tables.

In navigation we make uſe of ſeveral tables; but the chief are the tables of the ſun's declination, thoſe of his right aſcenſion, of his riſing and ſetting, of his eaſtern or weſtern amplitude, and of his azimuth, or of his hour for his ſeveral heights. The conſtruction of all which follows. Farther on ſhall likewiſe be given a loxodromic table.

1. Borrowing from Aſtronomers a table of the ſun's longitude for every day at noon, with the

greateſt declination of the ſun, which is 23° 29′, and in conſequence thereof, ſuppoſing in Figure 17, A B C to repreſent the equator, EBD the ecliptick, HFI a meridian, FB the given longitude of the ſun for each day, FG the declination correſpondent to the given longitude, and the arch DC, or the angle FBG the ſun's greateſt declination; we ſhall be thence furniſhed with the following analogy, according to the 1ſt prop. of *Spherical Trigonometry.*

Fig. 17.

Sine total : *ſine* BF : : *ſine* FBG : *ſine* FG.

That is to ſay, the ſine total is to the ſine of the ſun's longitude as the ſine of the greateſt declination, to the ſine of the declination anſwering to the longitude given.

2. In the ſame manner may be found the arch BG, the neareſt diſtance of the ſun from the neat equinoctial point, by prop. 2. *Sph. Trig.*

The tangent of the greateſt declination F B G: *radius or ſine total* : : *the tangent of the declination* FG : *ſine of* BG *the ſaid neareſt diſtance.*

From which, to find the right aſcenſion, ſee page 17.

3. To get the amplitude, let EBD repreſent the horizon, ſo that FB may be the eaſtern or weſtern amplitude; the point F remaining the place of the ſun, and the arch FG its declination, and then the angle DBC will be the complement of the latitude of the place. Which will furniſh the following analogy (by prop. 1. *Sp. Trig.*)

Fig. 18.

The ſine of the compl. of the latitude B : *ſine of the declination* FG : : *ſine total* G : *ſine of the amplitude* FB.

4. For the hour of the ſun's riſing and ſetting; it is to be obſerved in the ſame figure, that if the declination and the latitude of the place, are both towards the ſame pole, the arch GC will be the hour of the ſun's riſing, and the arch GA that of its ſetting; but if the declination of the ſun be one way, and the latitude of the place the other, the arch GA will be the hour of the ſun's riſing, and the arch GC that of its ſetting. It will therefore follow that, *Fig.* 18.

The tangent of the ſine B *the compl. of the latitude* : *tangent of the declination* FG : : *ſine total* : *ſine of* GB *the compl. of the arch* GC, *or* GA.

5. Thus may be calculated a table of the hour and azimuth of the ſun at all heights, for any place whoſe latitude is known. For let AB be the equator, E the poles of the world, G the ſun, its height above the horizon GL, its declination GH; the azimuth will be the angle GFE, which may be known by the reſolution of the triangle GFE, whoſe three ſides are known, *viz.* GE the compl. of the declination, FE the complement of the latitude of the place, and FG the compl. of the ſun's height. For by cor. prop. 5. *Sp. Trig.* *Fig.* 19.

1. *Add the logarithmic ſine of the compl. of the latitude, and of the compl. of the ſun's height together.*

2. *Double*

2. *Deuble the log. of radius or the ſine total.*

3. *Add the log. anſwering to the ſine of half the arch compoſed of the compl. of the declination, and of the difference between the latitude and the height, to that which anſwers to the ſine of half the difference between the compl. of the declination, and the difference of the latitude, and of the height.*

Subtract the firſt term from the ſum of the remaining two, and the half of the remainder will be the log. of half the azimuth GFE.

The ſame muſt be done to have the angle GEF, which being divided by 15 will give the hour from noon; only obſerving to put the height inſtead of the declination, in ſuch ſort that wherever the declination is uſed in the firſt operation, the height is to be made uſe of in the ſecond, and ſo reciprocally.

PART

PART II.

Of SAILING by the SIGNS.

PROP. IX.

Of a Ship's Courſe.

1. WHEN a ſhip ſails due north and ſouth, the line ſhe deſcribes is a true meridian, each degree of which is nearly 60 thouſand geometrical paces.

2. When a ſhip ſails eaſt or weſt under the equinoctial line, her courſe is the equator its ſelf, the degrees of which are equal to thoſe of the meridians: But ſailing conſtantly at the ſame diſtance from the equator her courſe deſcribes a parallel thereto; the degrees of which are to thoſe of the equator, as the ſine compl. of their latitude to the ſine total (by prop. 7.)

3. When a ſhip ſails upon a rumb line, which makes an acute angle with a line due north and ſouth, her courſe does not form a circle, becauſe

it deſcribes a line making the ſame acute angle with all the meridians, which no circle can do. For example, let CD repreſent the equator, AB any meridian, and EF the ſhip's courſe, I ſay EF is not the arch of a circle. *Fig.* 20.

Demonſt. Since the ſhip keeps the ſame point of the compaſs in running through the line EF, all the angles made by the courſe EF with the ſeveral meridians will be equal, and moreover by the ſuppoſition acute. But if EF was a portion of a circle, it would make a right angle with the meridian paſſing through its poles (by ſup. 6. *Sph. Trig.*) and with the other meridians, angles more or leſs acute, in proportion as they are nearer or farther from that.

4. The courſe EF will be a curve line, compoſed of an infinite number of right lines: To explain this matter, ſuppoſe that in parting from the point E, the ſhip holds a courſe which makes with the meridian the angle AER, ſome one meridian as AR, muſt meaſure this angle, and that meridian will fall perpendicular upon ER; now the angle AER, will be more acute than the angle AKR, which the ſhip will make with the next following meridian, if ſhe deſcribes the arch ER; therefore when the ſhip comes to the point K, ſhe muſt quit the arch EKR, and fall into the line KH, ſo that the angle AKH, may be the ſame as the angle AER; but the ſhip's courſe, be it ever ſo ſmall, muſt meet with an infinite number of different meridians, it therefore follows, that ſhe muſt continually deviate from the circle ER, *Fig.* 20.

and thoſe that ſucceed it, and that her courſe muſt be compoſed of an infinite number of lines, of which each will be part of the ſhip's keel, and conſequently a right line.

REMARK.

A ſhip's courſe deviates more from the equator, or approaches leſs towards it, than if it deſcribed a great circle; becauſe in order to make the angles equal, the courſe muſt approach ſomething towards the neareſt pole. For ſuppoſing G the place of departure, when the ſhip comes to the point L, continuing the great circle, the angles would become leſs acute; and conſequently to keep them equal, the ſhip muſt leave the arch LE, and fall into LM, which will carry the courſe towards the pole B. It was ſaid, that the angles which any one circle makes with the meridians, would become leſs acute in proportion as they approach the equator, or the line; becauſe in approaching the line, they become more diſtant from that circle with which they make a right angle, or whoſe poles or moſt diſtant points are in the equator, upon which the poles of all the meridians fall.

PROP. X.

Of the Loxodromick Curve.

Let us ſuppoſe the courſe AB compoſed of an infinite number of right lines, making the ſame angle C A B with all the *Fig.* 21. meridians: We may then imagine an infinite number of right lines CD, perpendicular to the meridians in the points C, which with the parts of the meridians CA, likewiſe right lines, will form an infinite number of rectangled triangles A C D, right-lined and ſimilar to each other, which will furniſh us with the following reflections.

1. All the baſes AD of theſe triangles make up the ſhip's courſe; all the ſides AC make up the arch AL, or the ſhip's advance in latitude; and all the ſides CD make up a mean arch between AF and EB, or the ſhip's advance in longitude.

2. All the baſes AD of the triangles ACD, are to all the ſides AC, or to all the ſides CD; as any one baſe AD, to one ſide AC, or one ſide CD; ſo that giving to one baſe AD, the value of all the baſes; and to one ſide AC, or CD, the value of all the reſpective ſides; by the reſolution of the right lined and rectangled triangle ADC, we obtain the reſolution of the loxodromick curve AAB.

PROP. XI.

Of a Ship's reckoning.

1. To make a judgment of a ſhip's way, we muſt regard the force of the wind, the number of ſails, and the manner in which they are ſet, but above all muſt be conſidered, the rapidity of the water paſſing along the ſides of the veſſel; all which with good experience may enable a man to make a tolerable reckoning, eſpecially in a ſhip he has before tried.

2. The *Log* is a piece of wood of half a foot long, and two inches broad, cut into the ſhape of a boat, as A B, underneath which is fixed a little lead by way of ballaſt; this log is faſtened to a line by two cords, one of which is faſtened at the point A, and the other at the point B is only held by a pin thruſt into a hole, out of which it may eaſily be recovered. The log being thus prepared, when they would judge by it the ſhip's way, they throw it into the ſea over the ſtern, and veer out the line as the ſhip advances to the length of 20 fathoms; obſerving by a half-minute glaſs the number of fathoms run out in that time; if then the number is 25, they conclude the ſhip makes one league an hour: For if 30″ give 25 fathoms, 60′ or an hour will give 3000 fathoms, or one league, the ſhip then makes ſo many leagues an hour as the log runs out 25 fathoms in half a minute. It will therefore be eaſy to divide the log line in the following manner: Meaſuring 20 fathoms from the log, there place a white mark, as viſible as may be; then at the end of 6 fathoms and $\frac{1}{4}$, place a mark for $\frac{1}{4}$ of a league; and at 6 fathoms and $\frac{1}{4}$ further, a mark for $\frac{1}{2}$ a league, &c. *Fig.* 22.

3. I ſhall not ſtop here to conſider thoſe machins with wheels, which ſome authors have propoſed for the ſame purpoſe. The ſight of the ſea itſelf is ſufficient to ſhew their uſeleſneſs.

PROP. XII.

Of the difference of Latitude.

The difference of latitude between the place of departure, and that of arrival, may be found ſeveral ways.

1. Take the ſun's height at noon, and to the complement thereof, add the ſun's declination for the time, if it be on the ſame ſide of the equator with your zenith, and if it be leſs than the ſaid complement, the ſum ſhall be the latitude of the place where you have taken the altitude: But if the declination of the ſun be on the other ſide of the equator, it muſt be ſubtracted from the comp. of the ſun's height, to find the latitude of the place.

Fig. 23.

To demonſtrate this rule, let us ſuppoſe AB the equator, G the zenith, CD the horizon, the arch AG will be the latitude of the place; and if we ſuppoſe the ſun at the point H, the arch HG will be the complement of its height, and HA will be its declination; but if the ſun be ſuppoſed at the point F, the arch FG will be the complement of its height, and FA will be its declination.

Demonſt. It is evident, that if the ſun be on the ſame ſide as the zenith, that is to ſay, if it be at the point F, the declination AF ought to be added to FG, the complement of the ſun's height, to give the latitude AG. On the contrary, if the ſun be on the other ſide the equator at the point H, its declination HA, ought to be ſubtracted from

HG, the complement of its height, to obtain the latitude AG.

It may happen in the torrid zone, that the zenith and the ſun may be both on the ſame ſide of the equator; but the ſun's declination may be greater than the complement of his height; as for example, f the ſun be at the point G, and the zenith at the point F; in that caſe FG, the complement of ts height, muſt be ſubtracted from GA its declination, to have the latitude FA.

2. The ſame thing may be done by the meridian ltitude of ſuch ſtars, whoſe declinations are known.

3. When the pole ſtar, and the third ſtar in the ail of the great bear, reckoning from the end, may be cut by a plumb line, take the height of he pole-ſtar, and if it be above the other, ſubract 2° 22′ 40″ or add the ſame quantity if it be below, and you will obtain the height of the pole, r the latitude of the place *.

4. Seve-

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* *By reaſon of the aberration of light the pole-ſtar's al-*
itude in its preſent approximation towards the pole, which
t a mean ratio is accounted about 19″ ½ *yearly, the quan-*
ity to be added to, or ſubtracted from the altitude of the
le-ſtar, to obtain the true elevation of the pole, is
° 2′ 12′ *on or about the 22d of* Sept. 1749, 2° 1′ 52″
the 22d of Sept. 1750, *inſtead of* 2° 22′ 40″ *as*
bove; but this variation is alſo various at different
imes in each year, by the earth's annual motion having
ſenſible velocity compared with that of light, whereby
is ſtar appears on the 21ſt of June 20″ *too far off the*
le in any poſition, and on the 21ſt of Dec. *as much too*
ar, as Mr. Gardiner, *in his practical ſurveying im-*
roved, page 106, *has rightly obſerved.*

4. Several tables may be made for correcting the height of the pole; but one of the moſt uſeful is that which is compoſed of the height of the neighbouring ſtars, when they are found equal with the height of the pole *.

I omit the other methods of diſcovering the latitude by taking altitudes, becauſe they are not ſo proper for uſe at ſea.

PROP. XIII.

Of the Longitude.

This is a problem which has hitherto been ſought in vain, I mean to find the longitude at ſea, with the ſame eaſe and certainty as the latitude.

1. Some have thought to find it by means of an exact pendulum, which being ſet to the meridian of their departure, may keep the exact time of their courſe, ſo that obſerving the hour at the place of their arrival, and comparing it with the hour of the place of their departure ſhewn by the pendulum, they thereby may ſee exactly the difference of the meridians; for, ſay they, if the hour found at the place of arrival, is earlier than the hour ſhewn by the pendulum, divide the

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* The table in this place mentioned (though inſerted in the original) is here omitted, by reaſon of the above-hinted variations of the pole-ſtar; and as the other ſtars are likewiſe more or leſs ſubject to ſuch variations, there can be no fixing of certain allowances for any duration; which muſt render ſuch table uſeleſs.

difference of the time by 4 minutes, and the quotient will give the number of degrees made eaſtward in the courſe. But beſides the difficulty of getting a pendulum not to be affected with the ſhip's motion, and the trouble of finding the hour exactly at ſea; the ſmalleſt error will be found conſiderable, becauſe 1 minute of time gives 15 minutes of longitude.

2. Thoſe who would make uſe of the moon's longitude, or the ſatellites of Jupiter to the ſame purpoſe, ſucceed ſtill worſe: Though indeed by the immerſions and emerſions of the firſt ſatellite of Jupiter, the longitude of a place may be found aſhore, where there is opportunity of frequently repeating the obſervation.

3. There remains therefore no means more certain for finding the longitude, than by the reſolution of the loxodromick curve.

PROP. XIV.

Of the Angles of the loxodromick Curve.

1. The angle oppoſite to the ſhip's way is right, and the angle oppoſite to the difference of longitude is given by the compaſs, being the angle of the rumb, or the angle made by the ſhip's keel with the meridian (by prop. 10). For which purpoſe the box of the compaſs is ſo diſpoſed, that the black line thereof may anſwer exactly to the ſhip's head; and ſo the rumb anſwering the ſaid black line, is the line of the ſhip's courſe, and the angle which this rumb line makes with the meridian, or the arch between the ſaid black line, and

the meridian upon the compaſs, gives the angle oppoſite to the longitude.

It is to be obſerved, that each rumb line or point of the compaſs gives an angle of 11° 15′, therefore multiplying the points of the compaſs between the black line and the meridian by $11\frac{1}{4}$, the product gives the angle oppoſite to the difference of longitude.

2. Care muſt be taken to correct the variation, that is, it muſt be added, or ſubtracted, as occaſion requires, to the angle given by the compaſs; there are many ways of doing this, but the moſt eaſy is to turn the black line of the compaſs in proportion, to ſtarboard or larboard of the ſhip's head, on the ſide the variation lies; for then the black line will give the rumb, or point of the compaſs corrected.

PROP. XV.

To reſolve the loxodromick Triangle.

The loxodromick triangle, which may be taken for a right-lined rectangled triangle, may be reſolved, if ſo much of its angles or ſides are known, as are neceſſary for its determination; and by this reſolution, we obtain the angles and ſides unknown.

SECT. I.

Departing from the latitude of 40° N. and being arrived at 42° by a N. N. E. courſe, it is required to find the diſtance ſailed, and the difference of longitude. That is to ſay, in the loxodromick triangle A B C, wherein the angle B is right, the difference of latitude

Fig. 24.

tude AB, and the angle of the rumb BAC are known; and the courſe AC, and the difference of longitude CB are required.

1. Multiplying the 2 degrees, the advance in latitude, by 60 miles, and the ſide AB is found to cointain 120 miles, and multiplying the 2 points between N. N. E. and the north point by 11$\frac{1}{4}$ the angle BAC is found to be 22° 30′, then form the following analogies;

Sine C, *comp. of* 22° 30′ : 120 *miles* : : *ſine total* B : *the miles of the courſe* AC 136.

Sine C, *comp. of* 22° 30′ : 120 *miles* : : *ſine* A : *the miles of the longitude* BC 52.

2. If you would reduce the miles of longitude BC into degrees, obſerve that theſe miles are run upon the different parallels between 40° at the departure, and 42° at the arrival, and therefore without any conſiderable error, you may ſuppoſe them run upon the parallel of 41° an arithmetical mean between 40 and 42. To reduce them then into miles of the equator, correſpondent to the miles run upon the parallel of 41°, uſe the following analogy.

Sine comp. of 41° : *ſine total* : : 52 *miles of the parallel* 41° : *miles of the equator* 69.

And thus you will find 1° 9′ for the difference of longitude.

SECT. II.

Departing from the latitude of 40° N. and arriving at 42°, after ſailing eaſtward 136 miles, 'tis required to find upon what point of the compaſs the courſe was held, and what the difference of longitude.

In the ſame triangle ABC we ſay,
136 *miles contained in the baſe* AC : *ſine total* : : 120 *miles contained in the line* AB : *ſine of the angle* C, *compl. of the angle* A.
Afterwards the difference of longitude is found as in the preceding ſection.

SECT. III.

Departing from the latitude of 40° N. and having ſailed 136 miles on a N. N. E. courſe, the difference of latitude, and the difference of longitude are required.

In the ſame triangle ABC we ſay,
Sine total B : 136 *miles* AC : : *ſine* C, *compl. of* A : *difference of latitude* AB 120 *miles, or* 2°.
The longitude CB is found as in Sect 1.

SECT. IV.

If the longitude and latitude be known in degrees, the point of the compaſs and length of the courſe may be found. For in the triangle ABC, the miles contained in the line AB may be found, by multiplying the degrees of the difference of the latitude by 60 miles; and further, the miles of the difference of longitude may be found, by multiplying the given degrees by 60, which will give the miles of the equator anſwering to the miles of the lines BC; then to find the miles of the line BC form the following analogy.

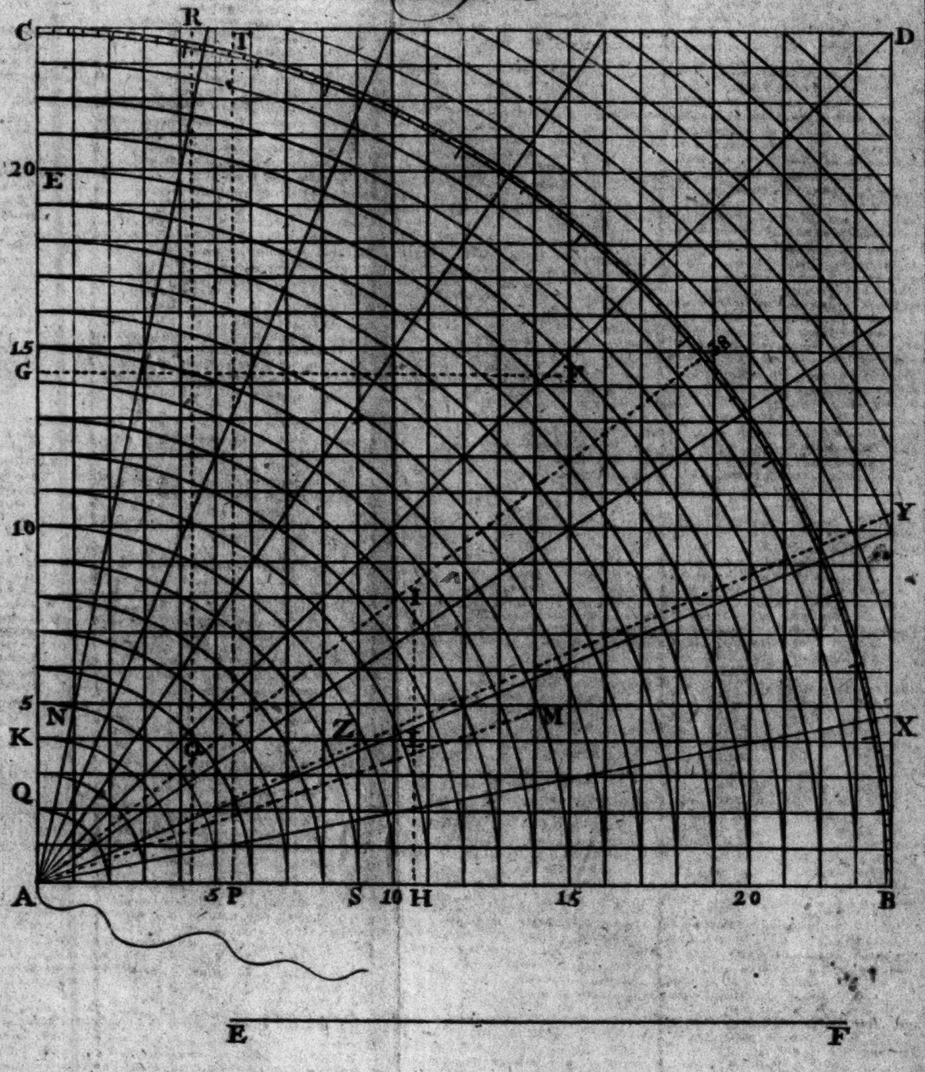
Fig. 24.

Sine total : *ſine comp. of the mean parallel between the departure and arrival* : : *the miles of the equator* : *miles of the line* CB.

After having thus determined the miles of the line AB, and of the line BC, form the following analogies.

Mil

Fig: 25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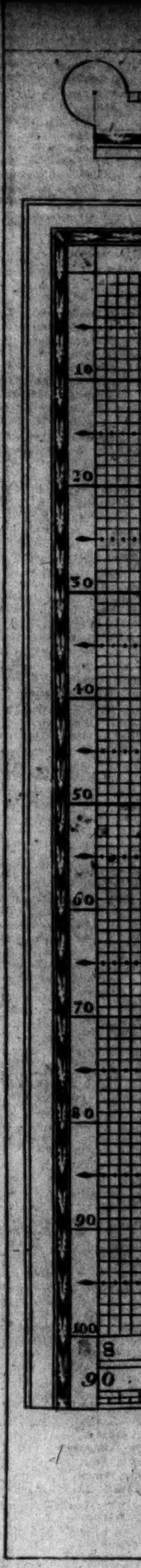

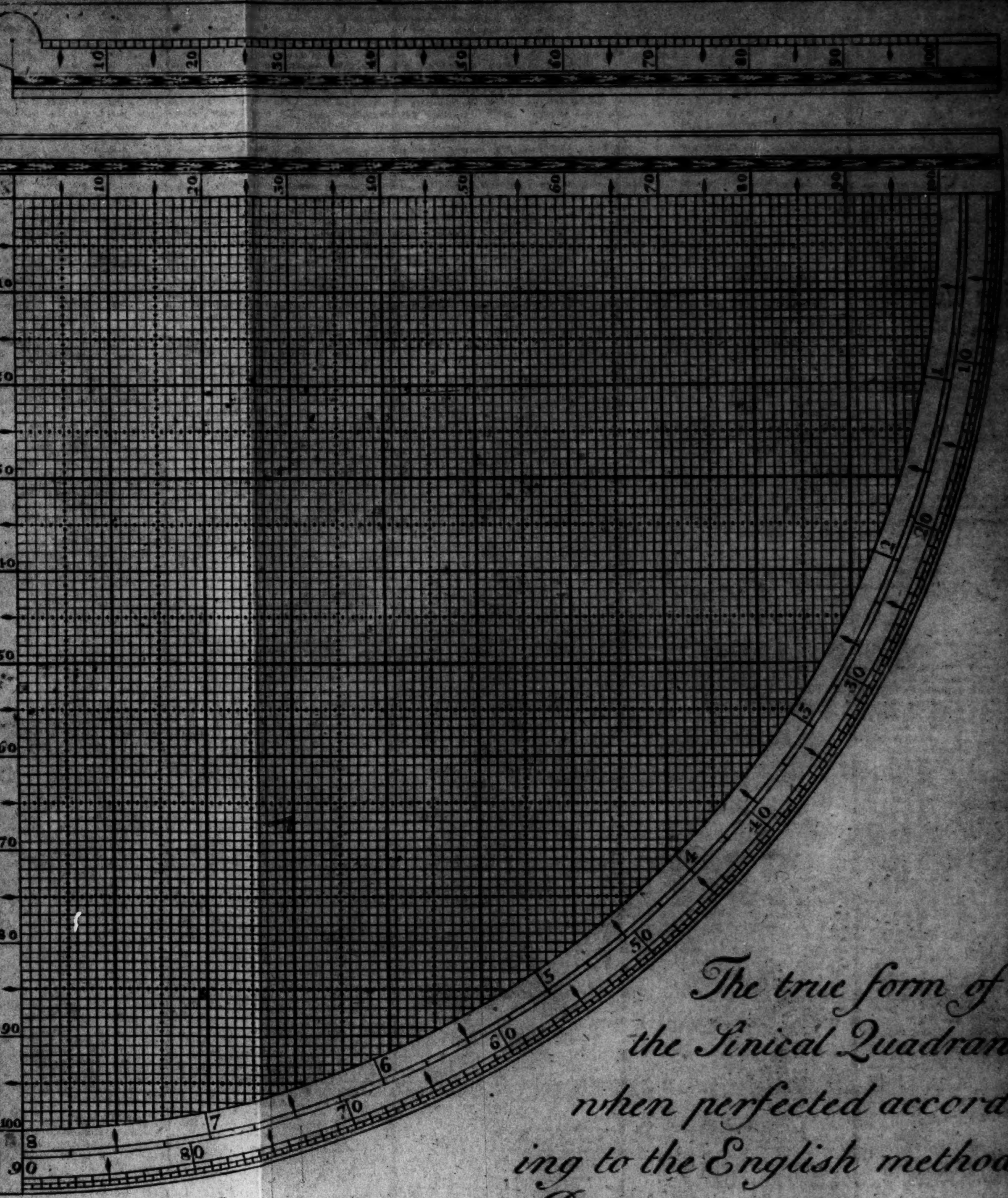

The true form of the Sinical Quadrant when perfected according to the English method of Projection

Miles of AB : *miles of* BC : : *ſine total* : *tangent of the angle of the rumb* A. Then,

Sine of the angle A : *miles of* BC : : *ſine total* : *miles of the courſe* AC.

REMARKS.

1. The ſame thing may be done with the longi-
de as with the latitude, ſince the longitude is
iven in miles, and not in degrees.

2. When the latitude of the departure, and that
f the arrival, are one ſouth, and the other north ;
requires two operations, of which the one ſhall
ke for the difference of latitude, the diſtance from
e departure to the line, and the other ſhall in-
ude the reſt. Alſo if the courſe be given, it muſt
divided as the latitude, by this analogy ;

Miles of the whole difference of latitude : *miles of the whole courſe* : : *the miles of the latitude in the firſt operation* : *miles of that part of the courſe.*

3. When a ſhip has made ſeveral different cour-
, it is eaſy to reduce them to one, after having
n, by the reſolution, what each gives with re-
ct to the four cardinal points ; for adding toge-
r all that tend toward one point, and ſubtracting
erefrom whatſoever tends to the contrary point ;
remainder will be the true difference in longi-
e and latitude, from whence may be deduced
true courſe, and the point of the compaſs or
nb line anſwering the ſeveral courſes. See the
lowing example.

	N.	S.	E.	W.
1 Courſe Degrees	2	0	1	0
2 - - - - - - -	0	3	2	0
3 - - - - - - -	4	0	0	5
Sum	6	3	3	5
	3			3
Value of the Courſes	3° North			2° Weſt.

SECT. V.

CORRECTIONS.

It often happens, that after you have reſolved the loxodromick triangle (by Sect. 3) with reſpect to the reckoning made of the ſhip's way, and the rumb line given by the compaſs, you may find, by ſome obſervation of an altitude, a latitude different from that found by the ſaid reſolution; and as an obſervation by an altitude is more certain, than either your reckoning, or the compaſs; either the one, or the other, or both, are to be corrected in the following manner. 1. If the courſe ſailed on is very near to a due north and ſouth line, the reckoning is corrected by making the reſolution by Sect. 1. 2. If the courſe ſailed on be nearly an eaſt and weſt line, we keep to the latitude and diſtance, and correct the rumb line by Sect. 2. 3. If the courſe ſailed on is nearly N. E. and S. W. or S. E. and N. W. we firſt correct the diſtance by Sect 1. then taking a mean diſtance between that of the reckoning, and that given by the correction, and by this mean diſtance, correct the courſe or rumb line. The reaſon of theſe practices is eaſily diſcovered.

PART III.

Of SAILING *without regarding the* SIGNS.

PROP. XVI.

Of ſailing by the help of Tables.

1. THE loxodromick table ſhews under each rumb the difference in longitude, and the diſtance anſwering to each difference in latitude.

2. The table conſiſts of ſeven columns; as ſeven rumbs are ſufficient to diſtinguiſh the whole compaſs, and by the help of this table, may be performed all the operations before done by the ſines. If we allow, for example, one degree of difference in latitude by the N. N. E. look in the column which gives 22 degrees 30′ for the rumb, the diſtance anſwering to one degree of latitude, to wit, 65 miles, will be the diſtance ſailed; and the 24′ of longitude oppoſite thereto, is the difference of longitude. In the ſame manner having ſailed 60 miles by the N. E. by N. I look in the column of the third rumb for 60, and I find over

againſt it 33′ for the difference of longitude, and 50′ for the difference of latitude.

3. Regard muſt be had to the latitude of the departure in the uſage of this table, and ſubtract that which goes before, from that which follows in the table, to find what you look for; for example, having departed from the latitude of 40′ N. and being arrived at the latitude of one degree N. after having ſailed 103 miles, I run through the columns of rumbs till I find one, where the diſtance anſwering to 40′, ſubtracted from one degree, *viz.* 20′, is 103 miles, and I find it to be the column of the ſeventh rumb, or of the E. by N. if I ſailed on the eaſt ſide. In the ſame manner I ſubtract the longitude anſwering to 40′, from that anſwering to one degree, and the remainder is 1° 40′ for the difference of longitude.

4. The conſtruction of this Table is eaſy; for having found (by Sect. 1.) the miles which 10′ in latitude gives under each rumb for the longitude, and for the diſtance, we ſet down twice the number for 20′, three times for 30′, &c. and then reduce the miles of longitude into degrees.

5. Thoſe tables which give the value of degrees of each parallel are not to be neglected: Their conſtruction will appear, from what has been before ſaid, in the ſeventh propoſition.

A LOXODROMICK *Table.*

Latitude.	1. Rumb. 11° 15′		2. Rumb. 22° 30′		3. Rumb. 33° 45′		4. Rumb. 45° 0′		5. Rumb. 56° 15′		6. Rumb. 67° 30′		7. Rumb. 78° 45	
D. M.	Long. D. M.	Courſe Miles	Long. D. M.	Courſe Miles	Long. D. M.	Courſe Miles	Long. D. M.	Courſe Miles	Long. D. M.	Courſe Miles	Long. D. M	Courſe Miles	Long. D. M	Courſe Miles
0 10	0 2	10	0 4	11	0 7	12	0 10	14	0 15	18	0 24	26	0 50	51
0 20	0 4	20	0 8	22	0 13	24	0 20	28	0 30	36	0 48	52	1 41	103
0 30	0 6	31	0 12	32	0 20	36	0 30	42	0 45	54	1 12	78	2 31	154
0 40	0 8	41	0 17	43	0 27	48	0 40	57	1 0	72	1 37	105	3 21	205
0 50	0 10	51	0 21	54	0 33	60	0 50	71	1 15	90	2 1	131	4 11	256
1 0	0 12	61	0 25	65	0 40	72	1 0	85	1 30	108	2 25	157	5 2	308

Note, *Theſe Longitudes anſwer to the meridional Difference of the Latitudes, and the Miles in the Courſes to the proper Difference of the Latitudes, as they are more truly corrected than in the former Editions.*

PROP.

Prop. XVII.

Of ſailing by the Quadrant.

The *Quadrant of Reduction*, (as it is called by the *French*) or *Sinical Quadrant*, conſiſts of a great ſquare divided into ſeveral ſmall ones, upon which may be found all ſorts of right-lined rectangled triangles, with their ſides divided into equal parts. The conſtruction will appear plain from the figure; only take notice that the ſcale EF, is a *Fig.* 25. ſcale of increaſing latitudes, or of ſecants, whoſe radius is equal to one of the equal parts of the quadrant. The nine lines drawn from the center A, repreſent all the rumbs of the wind; the line AC ſerving for the north and ſouth, and the line AB for the eaſt and weſt.

SECT. I.

Having ſailed between the 36th and 40th degrees of north latitude, and having advanced 85 miles towards the eaſt, it is required to know the degrees of longitude anſwering the ſaid 85 miles; or, which is the ſame thing, it is required to find how many miles of the equator are equal to theſe 85 miles: And this is what is called reducing the miles of longitude, to miles of the equator.

There are two ways of reſolving this queſtion by the quadrant.

1. Take upon the line AC, ſo many parts as there are degrees of latitude between the departure and arrival, *viz.* 4, and you will have AK, then extend the compaſſes upon the ſcale EF from 36 to 40, and carry that extent from A to N; then counting upon the parallel KL 85 parts to L,

reckoning 8 to each diviſion of the quadrant, and the line AL cutting the parallel NM in the point M, gives upon NM, the miles of the equator, anſwering to the miles of the parallel, *viz.* 104 equal to 1° 44′. The demonſtration is founded upon this, that the line AK will be to the line AN, as the ſine total to the ſecant; or as the ſine complement to the ſine total; and conſequently, KL will be to NM, as the miles of the parallel, to the miles of the equator (by *Prop.* 7.)

2. Extend the thread of the quadrant from A to the 38th degree of the arch BC; becauſe 38 is the mean between 36 and 40, then counting upon the line AB, 85 parts to the point H, reckoning 8 parts to each diviſion of the quadrant; the parallel HI cutting the thread in the point I, will give the miles of the equator upon IA; ſince in the triangle AHI, the ſide HA is the ſine complement of the mean parallel 38, and IA is the ſine total; accounting therefore 8 parts to each diviſion of IA, you will find 104 miles or 1° 44′.

3. If you would change the degrees of longitude into miles, firſt reduce them into miles of the equator, which are meaſured upon the line MN, or AI, to have the lines KL, or AH, in reverſing the operation.

SECT. II.

Sailing from the latitude of 36° N. and having run 120 miles upon a N. W. courſe, it is required to find the difference in longitude, and in latitude.
1. Reckon upon the line AC 120 parts from A to E, allowing 6 parts to each diviſion of the

quadrant.

quadrant. Then having extended the thread from A to E, ſet it off upon the line AD which repreſents the N. W. and it will give the point F, and the rectangle triangle AFG will repreſent the loxodromick triangle, whoſe ſide AG will be the difference in latitude, and the ſide GF the difference in longitude; allowing therefore 6 parts to each diviſion of theſe ſides, you will find 85 miles, or 1° 25′ for the difference in latitude, and 85 miles for the difference in longitude, which you may reduce into degrees (by the prec.)

SECT. III.

Sailing from 36 degrees of north latitude, and having run 120 miles towards the eaſt, it is found by an obſervation, that the ſhip is arrived in 37° 25′ N. it is required therefore to find the rumb, and difference of longitude.

1. Reduce the difference of latitude, which is 1° 25′ into miles, which will be found 85, and reckoning them upon the line AC, from A to G, accounting 6 to each diviſion; reckon likewiſe 120 upon the ſame line to E, and extending the thread to E, move it about till it cuts the parallel GF in the point F, ſo ſhall you have the loxodromick triangle AFG, whoſe angle GAF of 45°, will give you the N. W. rumb line, and the line GF will give you 85 miles for the difference in longitude, which may be reduced to degrees (by Sect. 1.)

SECT. IV.

Sailing from 36 degrees of north latitude, and 100 degrees of longitude, a ſhip is to be brought to a place in the latitude 37° 25′ N. and in the longitude of 97° 39′, it is required to find her courſe and diſtance. Reduce both the longitude and latitude into miles, and you will find 85 miles anſwer both to the one and the other, which you are to number upon the line AC for the latitude to the point G, and for the longitude, from the point G upon the parallel GF to the point F; ſo ſhall the line FA be the diſtance, *viz.* 120 miles, and the angle FAG will give the rumb line or courſe, *viz.* N. W.

SECT. V.

Departing from 36 degrees of north latitude, and having ſailed to 37° 25′ upon a N. W. courſe, it is required to find the diſtance ſailed, and the difference in longitude. Reckon the miles of the difference in latitude, *viz.* 85, upon AC to G, the parallel GF cutting the N. W. rumb in the point F, gives FA for the diſtance ſailed, and FG for the difference in longitude.

REMARKS.

1. There is nothing particular with reſpect to corrections, upon the quadrant.

2. The analogies may be all worked on the quadrant, without recourſe to the table of ſines: For example,

To find the amplitude, there is given the following analogy.

The ſine compl. of the latitude : ſine total : : ſine of the declination : ſine of the amplitude.

Suppoſing then, that we were to ſeek the amplitude in a place whoſe latitude is 38°, and that the ſun's declination was 10°, extend the thread from A to the 38 degree of the arch BC, and taking CR of 10°, the parallel RO will cut the thread in the point O; transfer AO upon AP, and the parallel PT ſhall cut the arch BC in 12° 33′, which will be the amplitude. The reaſon of which is, that in the operation 38 G, the ſine compl. of the latitude, is to 38 A the ſine total, as QO, the ſine of the declination, to AO, or AP, which will conſequently be the ſine of the amplitude (by 4. 6. *Eucl.*)

3. In the ſame manner may be done thoſe analogies, where the tangents and ſecants are made uſe of. For example, ſuppoſe this analogy,

> *Tangent of the ſun's greateſt declination* : *tangent of the declination of* 10 *degrees* : : *ſine total* : *ſine of the ſun's diſtance from the neareſt equinox*.

Extending the thread through the 10° of the arch BC to get the tangent XB, and having transferred it upon the point Y, ſo that it may paſs through 23° 29′, which is the ſun's greateſt declination, I find the parallel XZ cuts in the point Z, and the parallel ZV cutting the arch BC in the point V, will give VC for the arch ſought. For ſo the tangent YB of 23° 29′ will be to the tangent XB, or ZS of 10°, as the ſine total AB, to the ſine SA, or V to that which will conſequently be the arch ſought (by 4. 6. *Eucl.*)

PROP.

Prop. XVIII.

Of ſailing by Charts.

The ſame rules before given, concerning the chart of diſtance, may be applied to the reduced chart with more eaſe and certainty in taking the ſcale of latitude.

SECT. I.

Departing from the point A, and having made two degrees to the north, *Fig.* 26. and 240 miles to the weſt, the place of arrival is required. The 2° reduced, make 120 miles which taken upon the ſcale, are to be laid down from A to B northwards, upon a line parallel to a line N. and S. then taking upon the ſcale 240 miles, lay them down weſtward, upon a line parallel to a line E. and W. and you will find the point of the arrival C: So that the line AC will be the diſtance ſailed, and the rumb line upon which the courſe was made.

SECT. II.

Departing from the point A in the latitude of 48° N. and having made a N. W. courſe; by an obſervation at noon, the latitude is found to be 48° 45′ N. it is required to find the place of arrival. Take 45 miles from the ſcale, and laying them down due north, you will find the point D, from whence drawing the line DE to the weſt, and from the point A the line AE to the north-weſt, the interſection E will be the place ſought.

SECT.

SECT. III.

Departing from the point A, and having made 150 miles upon a N. N. W. courſe, the point of arrival is required. Take 150 miles on the ſcale, and lay them down on a line parallel to the N. N. W. and you will find the point F, the place of arrival.

SECT. IV.

Departing from the point A, after having ſailed 130 miles, it appears by an obſervation, that the ſhip has advanced 30′ towards the north, it is therefore required to find the place of her arrival. From the point A, lay down 30 miles due north to G, and draw GH due E. and W. then taking 130 miles, with that diſtance from the point A, make an arch cutting the line GH in the point H, which point H will be the place of arrival.

Note, The arch is made to the eaſt or weſt, according as the courſe was held.

SECT. V.

Being within ſight of land, the point A is found to bear S. E. and the point B eaſt; it is required to find the place of obſervation. Thro' the point A draw a line parallel to the S. E. and through the point B a line parallel to the line due eaſt and weſt, and the point C, where the two lines interſect, will be the ſtation or point of obſervation.

SECT. VI.

In the ſame manner, if we were at 130 miles diſtance from the point A, and at the diſtance of 85 miles from the point G; from the point A deſcribe an arch with the radius of 130 miles, and from the point G, another with the radius of 85, ſo will the point where the arches interſect each other, give the ſtation.

REMARKS.

Theſe operations are eaſily perform'd with a pair of compaſſes; for if one point be run along any line, the other point will deſcribe a line parallel thereto, ſince the compaſſes will keep the diſtance they are ſet to, which diſtance may be look'd upon as a line perpendicular to that upon which one of the points runs.

I ſay nothing of keeping a journal, ſince the court has preſcribed a certain method, which all are to follow; beſides that my deſign is not to offer every thing that relates to navigation; but only what more immediately depends on the mathematics, otherwiſe ſeveral large volumes would hardly be ſufficient.

PROPOSITION the laſt.

Of Tides and Currents.

By the Tide we mean that flux and reflux of the ſea, which is perceptible upon the coaſts of the *Mediterranean*; but much more ſenſible on the ſeveral coaſts of the ocean. The tides then, are that riſing and falling of the ſea, which is obſervable twice every lunar day, under the following circumſtances. 1. The waters are forced towards the ſhoars, during 6 hours before high tide, and this motion of the waters is called the *Flood*; in like manner they retreat again for 6 hours before low water, and this laſt motion is called the *Ebb*. 2. High tide does not happen at the ſame time in all places; but each place has a particular time for its tide.

3. The time of the tides is not according to the hours of the ſun, but according to the hours of the moon, and as the lunar hours are later every day by 48′, the tides are in the ſame proportion of time later. 4. The tides are higheſt at the full and new of the moon, at the times of the equinoxes, and moſt eſpecially at the autumnal equinox.

COROLLARY.

To determine the time of high tide at any place for each day, two things are to be known. 1. At what hour of the moon, the tide comes to that place. 2. What hour of the ſun anſwers to that lunar hour for each day.

SECT. I.

Of the Situation of Ports.

1. The ſituation of a port is that point of the compaſs, ſhewing the hour of the moon when high tide happens in ſuch port. Pilots diſtinguiſh the hours of the moon by the points of the compaſs, beginning by the north and ſouth, upon which they place mid-day and mid-night, allowing to each point of the compaſs $\frac{3}{4}$ of an hour. Thus when it is ſaid that *Breſt* (or *London)* is ſituate N. E. and S. W. 'tis underſtood that high tide happens there at the third hour of the moon.

2. To find the ſituation of a port, it muſt once be obſerved, at what hour high tide happens, and then ſee what hour of the moon anſwers that day to the ſaid hour obſerv'd, as ſhall be ſhewn below. For example, the 16th of *April* 1729, I obſerve at *Breſt* (or *London)* that high tide happen'd at 2 hours $\frac{1}{4}$, and I know that that day 2 hours $\frac{1}{4}$ an-

ſwers to 3 hours of the moon; therefore I conclude, that the ſituation of *Breſt* (or *London)* is 3 hours, or N. E. and S. W.

SECT. II.

Of the Hour of the Moon.

The hour of the moon is the ſame with that of the ſun at the time of new moon; loſing every day 48′ or $\frac{4}{5}$ of an hour. Knowing therefore the number of days ſince new moon, we eaſily know what time the lunar hours are behind the ſolar. For example, if the moon is 6 days old, multiply 6 by $\frac{4}{5}$, and you will find 4 hours $\frac{4}{5}$, or 4 hours 48′, the time the moon has loſt with reſpect to the ſun, whence you may conclude, that noon by the ſun anſwers to 7 hours $\frac{1}{4}$ of the moon.

SECT. III.

Of the Moon's Age.

By the moon's age, we mean the number of days paſſed ſince the new moon. To determine the moon's age, we muſt ſuppoſe as follows:

1. That the lunar month is ſhorter than the ſolar, nearly by one day, and conſequently the lunar year falls ſhort of the ſolar year by above eleven days.

2. That the year before the birth of Chriſt, a new moon happen'd upon the firſt of *March*; but the year after, the new moon fell out 11 days before the firſt of *March*; nor did the new moon happen again upon the ſame day, till after a revolution of 19 years: Thus every 19 years, beginning from the year before the birth of Chriſt, the new moon falls

upon the firſt day of *March*; and theſe 19 years make up one compleat revolution of the moon.

3. The moon's age cannot exceed 30 days; therefore in every calculation of the moon's age, 30 muſt be thrown out as often as it is found.

4. The epact is the moon's age at the beginning of *March*; it ariſes therefore from the addition of 11 days to the moon's age each year.

5. The golden number is the number of years paſs'd ſince the laſt revolution of the moon.

6. To find the golden number, add 1 to the current year, and dividing the ſum by 19, the remainder ſhall be the golden number. For example, to find the golden number for the year 1729, divide 1730 by 19, and the remainder wil be 1 for the golden number.

7. To find the epact, divide the golden numbe by 3, and if 0 remains, the epact is the ſame wit the golden number; if there remains 1, add 10 t the golden number, and if there remain 2, add 20 and the ſum (rejecting 30, if exceeding that number, as above directed) will accordingly be the epa For example, to find the epact for the year 172 divide the golden number of the year, *viz.* 1 by 3 and as the remainder is 1, add 10 to 1, the golde number, the ſum is 11 for the epact. The re ſon this rule is founded upon is, that as the ep increaſes every year 11 days, and the golden nu ber 1 day, therefore to the golden number muſt b added ſo many times 10, as there are units abo 1; but as every 3 years make 30, which muſt b deducted, it is better not to add the tens till af you have thrown out all the threes.

8. Havi

8. Having the epact, to find the moon's age for any given day, to the epact add the number of months paſs'd ſince *March*, and the number of days paſs'd of the current month. Thus to find the moon's age for the 6th of *July* 1748; to the epact 11 add 4 for the months paſs'd, and 6 the given day of the current month, and you will find 21 for the moon's age.

SECT. IV.

Of the Time of high Tide.

Having the moon's age, and the ſituation of the port, the time of high tide is thus found: multiply the moon's age by 4, and divide the product by 5, the quotient gives the hours, and multiplying what remains by 12, you will get the minutes, which time being added to the ſituation of the port, gives the time of high water. For example, to find the time of high tide at *Breſt* (or *London*) for the 6th of *July* 1729, multiply he moon's age, which is 6 days (after having leducted 15 days, which brings the moon to the ull, and the tide to the hour of the ſun, as at ew moon) by 4, the product will be 24, the irſt part of which is 4 hours, and the remainder ultiplied by 12, gives 48′, adding therefore hours 48′, to 3 hours, the ſituation of *Breſt*, I nd the time of high tide for the ſaid day, 7 ours 48′.

SECT. V.

Of Currents.

We oftentimes attribute to imaginary currents, e error ariſing from the wrong diſpoſition of e coaſts in charts, as in the gulf of *Lions*, here the cape of *Quiel* is really much more weſtward than it is laid down; nevertheleſs we cannot deny but there are currents, and more eſpecially near land; and that it is of the utmoſt importance to have a due knowledge of them. It is no great difficulty to judge of them when within ſight of land; but out at ſea the moſt eaſy method is, to ſet out the boat, and throwing out a heavy grapling or other conſiderable weight, with as much line as poſſible, the boat, as if at anchor, will vere with the wind, if there be no current; but if there be a current, and little or no wind, the boat will then drive with the current, and plainly enough ſhew which way it ſets.

OF THE WORKING OF A SHIP.

ADVERTISMENT.

THO' the working of a veſſel is, without diſpute, the moſt important knowledge with regard to the ſea-ſervice, yet no one hitherto has writ a compleat treatiſe on the ſubject. F. Pardies, *indeed, in his tract of local motion, has, in few words, given great light into this matter; nor would it be difficult, from the principles he has advanced, to deduce all that may be thought neceſſary on the ſubject. The Author of the Theory of working a ſhip, has entered into the matter more largely, and moſt ingeniouſly and ſolidly determined four or five of the moſt difficult propoſitions. The tract, called* The exerciſe of working a ſhip, *is alſo a very uſeful work, and* *muſt*

muſt be acknowledg'd a production ſuitable to tha great capacity, which all France *admires in its moſt illuſtrious Author. Nevertheleſs, theſe ſeveral works not ſeeming to me ſufficient to give a perfect knowledge in this art, I have undertaken the following tract, wherein I have endeavoured to explain in order, all the ſeveral movements of a Veſſel, with the rules for their proper application. I have, in the cleareſt manner I was able, laid down all I thought proper for my deſign, believing I had more reaſon to fear cenſure, for omiſſions of any thing neceſſary to the inſtruction of thoſe for whom I write, than for the publication of what might otherwiſe have been better concealed from Strangers.*

Caution to the *Engliſh* Seaman.

To this advertiſement of the Author's concerning the original, I beg leave to ſubjoin the following caution to the Engliſh *Sailor, with reſpect to the tranſlation: That he would not be prejudiced againſt the work, upon ſometimes finding the* French *practice different from the* Engliſh: *For tho' the reaſons why a thing is done, may not be affected by the manner in which it is performed; yet if according to the worſt way of performance, the expediency of the thing be demonſtrated; certainly the better method is thereby more abundantly juſtified. Therefore as the Theory here laid down will be found univerſal, and as the* Engliſh *are confeſſedly the beſt navigators in the world, its application to their practice will conſequently appear the moſt natural; and will probably furniſh many uſeful hints for future improvements.*

Of the Working of a Ship.

BY the working of a ſhip, is here meant, the art of giving a veſſel all the motions of which he is capable, and the giving them properly.

We ſhall divide this tract into three parts. In he firſt of which we ſhall conſider the uſe and ffect of ſeveral inſtruments made uſe of to put a hip in motion. In the ſecond, the ſeveral ways f turning a ſhip. And in the third, lay down ules for navigating a veſſel upon the open ſea, om one port to another.

DEFINITIONS.

1. The *Motion* of a body, is that which carries ſucceſſively, from one place to another.

2. The *Direction* of motion, is the right line ong which the body is moved, or determined to ove, and through which it moves itlf in effect when free. Thus when e body A is determined to paſs along e line AB, the line AB, is call'd *The direction its motion*.

Fig. 1.

3. The *Wind* may be conſidered as a great mber of little bodies of air thruſt along in rallel lines. Theſe lines compoſe what may be ll'd a *Bed or Body of Wind*; ſo likewiſe a *rrent* is a great number of drops of water,

puſhed forward in parallel lines which form the *Body of the Current*.

4. In each of theſe lines which form the body of wind, may be conſidered two points, of which the neareſt to the riſe of the wind, is ſaid to be to windward of the other. For example, if the corpuſcules which compoſe the body of wind are thruſt from the points A, to the points B, we ſay the points A, and the points C, are to windward of the points B; and that the points B are to leeward of the points A and C. We ſay likewiſe, that all the points A, on the line AA, perpendicular to the body of wind, are equally to windward. The reaſon is, becauſe if two veſſels D and E, depart at the ſame time from two points of the line AA, and move with equal velocity along the lines E F and D F, equally inclined to the body of wind, they will meet each other at the point F, and neither ſhall paſs to windward of the other.

Fig. 2.

5. Suppoſing again, the wind to blow from A to B, if a veſſel made her courſe from B to A, it would be ſaid ſhe went in the wind's eye, or directly againſt the wind, which is impoſſible; ſo likewiſe, if a veſſel ſail along the line BG, ſhe would go leſs to windward, or leſs againſt the wind, than in the line BA; but more to windward than in the line BH.

6. We ſay a veſſel comes to the wind, or comes to, when ſhe ranges on a line more contrary to the direction of the wind; and that ſhe wares or falls off, when ſhe ranges on a line leſs contrary to the wind. For example, if a veſſel on the line

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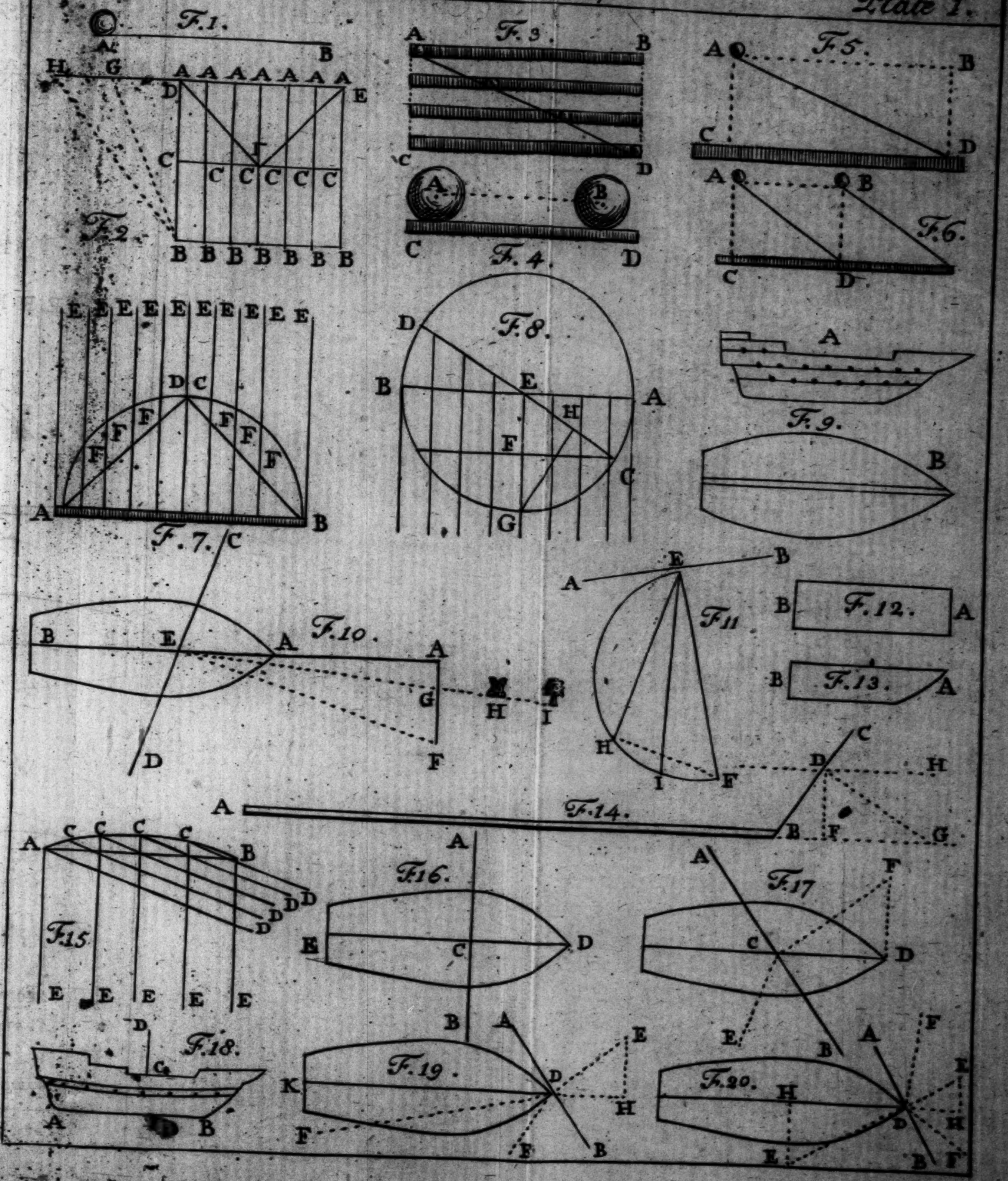
The Working of a Ship Plate 1.



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BH, ſhould range on the line BG, ſhe comes too; but if being on the line BG ſhe ſhould range on the line BH, ſhe wares.

7. When a veſſel keeps a line the moſt contrary to the wind that ſhe can ſail on, ſhe is ſaid to ſail upon a wind; but when ſhe runs upon a line nearly perpendicular to the courſe of the wind, we ſay ſhe ſails with a large wind; and having the wind right a ſtern, ſhe then ſails before the wind.

SUPPOSITIONS.

1. If in the ſame time that the body A, moves from A to B, in the canal *Fig.* 3. A B, the canal itſelf is carried from AB to CD, the body A ſhall move in the diagonal AD, and its true motion be compoſed of the motion carrying it from A to B, and of the motion whereby it is carried with the canal from AB to CD; that is to ſay, if the body A moves in the diagonal AD, two motions may always be diſtinguiſhed, one approaching the line BD perpendicular to the canal AB, the other approaching the line CD, parallel to AB.

2. A body in motion will only act on ſuch others as oppoſe it. Therefore the body A moving along the line AB, parallel *Fig.* 4. o the line CD of another body, will mpreſs no motion on it; but moving *Fig.* 5. n the line AC, perpendicular to CD, t will then communicate all its motion. Farther, f the motion of the body A be along the diagonal AD, it will communicate in the point D, only the

motion approaching the line CD; that is, it will make the ſame impreſſion as if it had fallen upon CD by the perpendicular AC, or BD, provided it took up the ſame time in running through BD, as it does in running through AD.

3. From whence it follows. 1. That when the body A falls upon CD, in the diagonal AD, its own motion is to that it communicates, in proportion as the ſine total AD, is to AC, the ſine of the angle of incidence ADC. 2. That the body A does not force the body CD, by the direction AD, but by a direction perpendicular to the face CD, *viz.* AC or BD.

REMARK.

Fig. 6. The body CD thus thruſt, does not in effect move in the direction BD, perpendicular to the face CD, but under two conſiderations. 1. That all parts of the body CD receive the ſame impreſſion, all being ſtruck in the ſame manner, or that the impreſſion made on the point D, which is ſuppoſed the center of gravity, be equally communicated to all the other parts. 2. That the ſeveral parts of the body CD have all the ſame ſacility of moving.

Fig. 7. 4. If an infinite number of cylinders EF, fall perpendicularly upon the fac AB of a body, they will have a greater effect than if they fell upon the two faces AC and BC; becauſe to the plane face AB, they would communicate all their own motion, but the faces AC, BC, only a motion in proporti to their own, as the ſines of the argles EFC, the ſine total: From whence it follows, that

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body AB will more eaſily divide the water in preſenting its two faces AC, BC, or its convex face A B C, than in preſenting its plane face AB. *

5. When the wind which ſtrikes a ſail, freſhens, two things happen: 1. Each of thoſe little bodies which compoſe the wind, puſh the ſail with greater force. 2. A greater number of thoſe little bodies ſtrike the ſail in an equal time. From whence it follows, that the motion which the wind impreſſes on the ſail, increaſes in a duplicate proportion to its velocity.

6. The difficulty which a ſhip finds in dividing the water, ariſes from that the water ſtrikes the ſhip with the ſame force, as if ſhe remained immoveable, and that the water came againſt her with the ſame velocity as ſhe moves againſt the water. From whence it follows, that the difficulty of a ſhip's cutting the water, increaſes in a duplicate proportion to her velocity; for the faſter ſhe moves, 1. Each particle of water ſtrikes againſt her with greater force: 2. A greater number of ſuch particles ſtrike againſt her in an equal ſpace of time.

7. From which obſervations it follows, that the velocity of a ſhip increaſes only as the roots of the forces which give it motion.

8. If

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* Of the motion of Fluids, and the Reſiſtance made to projected Bodies; Vide Sir *Iſ. Newton*'s *Principia*, Book II. Sect. 7.

8. If the ſail AB be perpendicularly oppoſed to the wind, and another equal ſail CD be ſet ſlant-ways, the impulſe on the ſail AB will be greater than on the ſail CD, in two reſpects; for 1. The force of each particle of the wind upon the ſail AB, in compariſon with the ſame particles on the ſail CD, is as the ſine total GE, to the ſine GH of the angle of incidence CEG (by *Sup*. 2.) 2. The quantity of wind which ſtrikes the ſail AB, in compariſon with the quantity of wind ſtriking the ſail CD, will alſo be as the ſine total EA, to the ſine FC, of the angle of incidence CEF. From whence it follows, that the impulſe upon the ſail AB, will be to that upon the ſail CD, in a duplicate proportion of the ſine total, to the ſine of the angle of incidence GEC, and univerſally the impulſes which a ſail receives from the ſame wind in different ſituations, are to one another as the ſquares of the ſines of the angles of incidence, which the wind makes upon the ſail.

Fig. 8.

PART I.

Of the INSTRUMENTS *made uſe of to put a Ship in Motion.*

PROP. I.

Of the Hull or Body of a Ship.

THE whole figure of a veſſel may be referred to two profiles, *viz.* the vertical A, and the horizontal B. *Fig.* 9.

1. The profile A, ſhews that a veſſel naturally preſents her head to the wind, and the profile B, ſhews that ſhe as naturally preſents her head to the current; for in that poſition only, the wind or current have the leaſt hold of her, and ſtriking equally on each ſide, keep her as it were in a perfect equilibrium.

2. It does not hence follow, that if the hull of a ſhip were floating at liberty in the middle of the ſea, that it muſt needs always preſent its head to the wind; becauſe in proportion as the ſhip gets ſtern-way, the water abaſt getting more power of her ſtern, forces it up againſt the wind; but the wind in its turn, as it thereby obtains a greater

hold, repels it back again; the ſhip therefore cannot keep one conſtant ſituation; but muſt ſometimes offer her head, ſometimes her ſtern; but moſt commonly her ſide to the wind.

3. 'Tis not the ſame in a current; for if the veſſel be therein free, ſhe will conſtantly preſent her head to the ſtream, for the reaſons before given; becauſe the water abaft, being carried on as faſt as the ſhip, does not conſequently ſtrike againſt her counter.

4. If a ſhip could be ſo fix'd in the ſea, as to turn eaſily about her center of gravity, ſhe would conſtantly preſent her head to the wind, or the current.

5. So likewiſe, if a ſhip without wind or current, was moved by a power applied to its center of gravity, which would admit its turning any way, ſhe would go head foremoſt, becauſe the water, which is ſuppoſed motionleſs, would have the ſame effect upon a veſſel in motion, as a current would have upon a veſſel not in motion.

COROLLARIES.

1. From theſe conſiderations, we ſee why ſhips ſo eaſily come to the wind, and why it is neceſſary to increaſe the head ſails, to make them ware.

2. The reaſon is as clearly ſeen, of a ſhip's falling off as ſoon as ſhe gets ſtern-way, and why ſo long in ſtaying when ſhe runs a-head; for when ſhe goes forward, the water ſtriking on both ſides, hinders her from readily turning either to the right or left; whereas in her recoiling or ſtern-way, the water abaf

abaſt thruſting up her ſtern, cauſes her to fall off, as ſoon as ever ſhe loſes her perfect equilibrium.

6. If a ſhip were perfectly round, ſhe would always keep the direction of motion given her; but being of a figure more adapted to cut the water with her ſtem, than with her ſides, ſhe does not always follow that direction of motion; for example, Suppoſe the veſſel AB, forced along by the ſail C D, whoſe direction is EF; if the veſſel were round, ſhe would keep the direction given, and ſail on the line EF, and conſequently the motion ſhe would receive from the ſail in this diſpoſition, is a compound of two motions, one carrying her ſtraight forward, the other ſide-ways. Or if the ſhip had the ſame difficulty to divide the water with her ſtem, as with her ſide, ſhe would keep the line EF; that is, ſhe would gain the length EA, right forwards in the ſame time, that ſhe would gain AF ſide-ways. But if a ſhip finds ten times the difficulty to divide the water with her ſide, as ſhe finds in dividing it with her ſtem, ſhe will then gain but the $\frac{1}{10}$ of AF, *viz.* AG, in the time of her gaining the length E A; and conſequently ſhe will be found at the point G, at the ſame time ſhe would have been at the point F, if it had been as eaſy for her to have divided the water with her ſide as with her ſtem.

Fig. 10.

REMARKS.

1. The line EG will be the true courſe of the veſſel, and the angle AEG the angle of variation. The line AG will always be to the line AF, as the difficulty the ſhip finds in dividing the water

by her head, is to that ſhe finds in dividing it by her ſide.

2. The angle AEG, changes, and becomes greater, in proportion as the angle AEF is increaſed; for the tangent of the angle AEG is to the tangent of the angle AEF, as AG to AF.

7. If any obſtacle abſolutely takes off the ſide motion of a veſſel, ſhe will keep the line EA, and will arrive at the point A, in the ſame time ſhe would have come to the point F, if ſhe could as eaſily have cut the water with her ſide as with her ſtem.

COROLLARY.

From hence it follows, that if a veſſel did not fall off, and a ſemi-circle were made *Fig.* 11. upon the line of direction EF of the ſail, the veſſel would arrive in the ſame time at any intended point of the ſemi-circle; that is, ſhe would come in the ſame time to the point H, or the point I, as to the point F, if ſhe had no more difficulty in dividing the water by her ſide than by her ſtem.

8. As all veſſels do not fall off alike, it is neceſſary to find the lee-way of any *Fig.* 10. particular veſſel; which may be thus done. Suppoſe the ſhip AB advancing towards ſome coaſt; take notice of ſome remarkable point, as H on the ſhore towards which ſhe is advancing, which you may obſerve two ways. 1. Set the point H by the compaſs from time to

time, and if you find it always in the ſame rumb, 'tis an infallible mark, that the ſhip ſails on the line EH. 2. If the point H anſwers to ſome other point as I, and continues to do ſo after the ſhip has ſail'd ſome time, it is evident the ſhip keeps her courſe EHI. When by one of theſe methods you find the ſhip keeps the line EGH, you may compare the angle AEG, with the angle AEF, by the following analogy;

The tangent AG *of the angle* AEG : *the tangent* AF *of the angle* AEF : : *the difficulty the ſhip finds in dividing the water by its ſtem* : *the difficulty of dividing the water by its ſide.*

REMARKS.

1. As the waves and currents render this experiment very uncertain, it muſt be frequently repeated, and that under different circumſtances.

2. The hull of a ſhip is alſo in ſome meaſure to be conſidered as a ſail, giving the ſhip a direction perpendicular to that of her keel; this direction with that of her ſails, compoſe a mean direction between EF, and EL, and with this mean direction the lee-way ſhould be computed: But as the thing is indeed impracticable, 'tis ſufficient to make the experiment as before directed, with the ſail ſet in different poſitions; when if the ſame ratio is conſtantly found between AG and AF, it may be concluded that the ſhip's hull makes no difference in the trial; but if the ratio of AG to AF, is found leaſt when the ſail is ſharpeſt trim'd, the difference is juſtly attributed to the ſhip's hull; and the remedy is to brace the ſail in proportion to ſuch difference.

9. If a ſhip AB, were of the ſame figure, both head and ſtern, we might from thence draw the following concluſions. 1. That if her *Fig.* 12. head A only, were puſh'd in a direction perpendicular to her keel, ſhe would turn about, and the center of her motion would be evidently in her ſtern B; ſo likewiſe if ſhe were puſh'd by the ſtern, ſhe would turn about her head A.

2. If ſhe be puſh'd at the ſame time on the ſame ſide, and with equal force in the points A and B, her movement will be in a line perpendicular to her keel. 3. But if ſhe be puſh'd on different ſides at the ſame time, ſhe will then turn about her center of gravity.

10. The form of a ſhip gives her a greater facility of dividing the water with her *Fig.* 13. head than with her ſtern: If the veſſel AB be puſhed by the ſtern B, with a direction perpendicular to her keel, ſhe will not turn about her head A, but about her center of gravity; whereas, if ſhe be puſhed a head with a direction perpendicular to her keel, ſhe will turn about her ſtern B, unleſs at the ſame time ſhe be puſhed on the contrary ſide a ſtern, for then ſhe will turn about her center of gravity. From whence it follows, that when a ſhip turns, ſhe almoſt always turns about her center of gravity; becauſe ſhe is almoſt always thruſt fore and aft on oppoſite ſides. Theſe rules are ſo plain they need no farther explanation.

PROP.

PROP. II.

Of the Rudder.

1. Suppoſe AB the keel of a ſhip, and BC the rudder inclined upon that keel; as the keel moves forwards, the water will have the ſame effect upon the rudder, as if the keel remained immoveable, and the water run a ſtern in lines parallel to the keel, with the ſame velocity as the keel advances; that is, the water will ſtrike the rudder by lines ſenſibly parallel to the keel, and puſh it back with a force proportionate to the velocity of the keel. *Fig.* 14.

2. All the parts of the rudder being ſtruck with the ſame force, it will be repell'd in the ſame manner as if the whole force which ſtrikes it were united in its center of gravity D. Draw the perpendiculars DF upon the keel continued, and DG upon the rudder: if then the abſolute force of the water be meaſured by the line BD, the impreſſion it makes on the rudder ſhall be meaſured by DF the ſine of the angle of incidence BDE, and the impreſſion of the rudder on the keel by FB the ſine of the angle of incidence BGD (by *Sup.* 2.) But ſince the impreſſion of the water on the rudder increaſes in a duplicate ratio of the ſine of the angle of incidence (by *Sup.* 8.) it may be concluded, that the force of the rudder upon the keel may be expreſs'd by the product of the ſine BF, multiplied by the ſquare of the ſine DF. Thus by a trigonometrical calculation may be found, the force of the rudder upon the keel in every poſition; and it will appear, that the moſt advantageous ſitua-

tion of the rudder, is when it makes the angle CBG with the keel continued of 54° 44′. For if the ſaid angle be made either more or leſs, the force of the rudder upon the keel will be diminiſhed. *

REMARKS.

1. Care ſhould be taken that the helm be never ſo far put over, as to make the angle CBG of the rudder with the keel more than 54° 44′.

2. Though the more the rudder be inclin'd, the more it ſtops the ſhip's way, it does not therefore follow, that the foregoing propoſition is the leſs exact, as the Author of the Theory ſeems to apprehend; ſince the impulſe of the rudder is given before the ſhip's way is loſt, and her after-motion, is according to the firſt ſtroke of the water againſt the rudder.

3. Another remark of the ſame Author's is better founded, for it is true, that a ſhip's not always advancing in a line parallel to her keel, does ſomething affect the ſaid rule; for the oblique

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* The Author here gives an algebraical calculation of the moſt advantageous angle the rudder can make with the ſhip's keel; as likewiſe he does at the end of the 18th Prop. of the moſt advantageous ſituation of the ſail with the wind; but as he has inſerted no Tract upon the ſubject of Algebra in his collection, but ſeems to have purpoſely omitted it throughout his whole ſcheme, I rather chuſe to leave out the ſaid calculations, than improperly (I think) introduce them into a Work, which the Author himſelf, in the projection of his Plan, ſeems to have thought compleat without Algebra.

lique way of a ſhip requires that the angle of inclination of the rudder with the keel prolong'd, be greater when the rudder is to leeward, and leſs when to windward.

4. When the rudder BC is to leeward, it puſhes the after part of the keel to windward, and makes the head of the veſſel fall to leeward ; on the contrary, if the rudder is to windward, it thruſts the after part of the keel to leeward, and makes the veſſel come to the wind.

5. This is to be underſtood when the ſhip has head-way ; but if ſhe goes a ſtern, the effect of the rudder is quite different, for the water which is behind her ſtrikes it in the direction HD ; ſo that in ſtern-way, if the rudder be to leeward, it brings her head to the wind ; if to windward, the contrary.

PROP. III.

Of the Sails in general.

1. Sails have the more force the higher they are hoiſted ; not becauſe the maſt is a kind of Lever, as ſome of the ancients thought ; for it is very certain their height does not increaſe their proper motion in that reſpect : But the greater force they obtain in that ſituation is occaſioned by the wind's blowing more freſh aloft, where its motion is leſs impeded by the vapours of the earth or ſea ; beſides that the higher the ſails are hoiſted, they are the more expoſed to the wind.

2. Sails have more force the taughter they are hoiſted, becauſe, 1. They catch more wind. 2. The

wind ſtrikes them more directly. 3. The impreſſion they receive is more uniform. For ſuppoſing the taught ſail AB, and the *Fig.* 15. concave one ACB; 1. The taught ſail AB, ſhall take as much wind, as the concave one ACB, though it be larger. 2. The wind communicates all its motion to the taught ſail, as it falls perpendicularly upon all its parts; but to the concave ſail, only a motion in proportion to the angles of incidence (by *Sup.* 2.) If the wind does not fall perpendicularly upon the ſail, but ſtrikes it obliquely by the lines AD, CD, BD, the wind will hardly have any effect on the windward part of the concave ſail, and its impulſe upon the leeward part, to which it is more perpendicular, ſerves ſcarcely for any thing elſe but to flat off the veſſel, becauſe it is nearly parallel to her keel; nay, it often happens, that that part of the ſail near the clue, when the ſheet is haled aft, proves intirely a back ſail, and is of great diſadvantage.

3. Theſe conſiderations ſhew how much they are deceived, who cut their ſails ſo as to bag in the middle, imagining that ſuch bagging gives the wind a greater power, eſpecially when ſailing cloſe upon a wind; whereas, indeed, the part ſo bagging out is hardly ſtruck at all by the wind, and is only fill'd with eddies from the adjoining parts of the ſail, which have no force at all.

4. For the ſame reaſons the top ſails have a greater effect upon a wind than the lower ſails; for the lower ſails not having yards to ſpread them at the foot, do not oppoſe the wind ſo flat. However in ſailing cloſe upon a wind, the lower ſails are not to be brac'd with the foot without board,

becauſe then not having a ſufficient power to trim them taught, they will become in a manner uſeleſs; they are beſt ſpread by belaying the tacks and ſheets to cleats, faſtened to the ſhip's ſide, in ſuch manner that they may be brac'd by the yards above, as the top ſails are by the yards below.*

5. So likewiſe thoſe top ſails, whoſe lower yards are too long, are not ſo fit for ſailing cloſe upon a wind, becauſe they cannot be hal'd ſufficiently taught. It is likewiſe proper the main ſail ſhould be ſo cut, that the parts neareſt the clue may not bagg when the ſhip is cloſe upon a wind, becauſe the direction of thoſe parts would rather hinder her way.

6. When the wind EC is perpendicular to the ſail A B, and the ſail AB perpendicular to the keel CD, the ſail AB is thruſt with the whole force of the wind, and communicates its whole motion to the keel, moving it a-head in the direction CD; ſo that this Diſpoſition of the ſail with the wind, and with the keel, is the moſt advantageous for making head-way with only one ſail: But in ſhips which

Fig. 16.

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* When a ſhip is to keep cloſe upon a wind, the *Engliſh* manner of trimming the ſails is as follows: The main-tack fore-tack, and mizzen-tack are brought cloſe by the board, and over-hal'd as forward as may be; the bowlines are the ſame on the weather ſide; the lee-ſheets are hal'd cloſe aft, but the lee-ſheet of the fore-ſail not ſo cloſe as the others, unleſs the ſhip gripes; the lee braces of all the yards are braced aft; and the top-ſails are braced, and govern'd as the ſails to which they belong.

which have many ſails in this diſpoſition, thoſe a-ſtern will keep the wind from filling thoſe a-head, therefore ſhips make moſt way when the wind is juſt a-baft the beam; at leaſt if there does not run too great a ſea. And ſome Corſairs in chaſing a veſſel which ſails before the wind, allow themſelves two points of the compaſs ſometimes on the ſtarboard, and ſometimes on the larboard ſide, in order to come up with her the ſooner. It is not altogether the ſame thing when the ſea runs high, for the waves ſtriking upon the ſhip's counter, ſupply the deficiency of the wind on the head ſails, and would make the ſhip fall very much off, if ſhe were not exactly in the direction of the wind.

Fig. 17. 7. When the ſail AB inclines with the wind, the impulſe it receives therefrom, decreaſes in a duplicate proportion of the ſine of the angle of incidence (by *Sup.* 8.) and when the ſail AB, inclines with the keel CD, it will communicate thereto all its own impulſe; but ſince its direction is not right a-head, the head motion it will impreſs thereon, will decreaſe as the ſine CD of its inclination with the keel.

8. Square ſails have a greater power than triangular ones, as being larger; but then they require more rigging, are more difficult, and ſlow in handing, beſides that they are more dangerous. From whence comes that diverſity of ſails made uſe of in different veſſels.

9. The moſt advantageous ſituation of a triangular ſail is, when the yard ſtands before the maſt;

maſt ; becauſe were it behind, 1. It would cauſe two baggings on the two ſides of the maſt, which would render a great part of the ſails uſeleſs. 2. The yard would bear harder upon the maſt, and make it more in danger of breaking. 3. The wind would have power of the ſail before it is brac'd, which would put the veſſel in danger of overſetting, if the wind ſhould take it when it is in a poſition parallel to the keel.*

PROP. IV.

Of the Head Sails.

1. The head ſails ſerve to keep the veſſel ſteady, hindring her from ſheering to and again ; for ſuppoſe AB the veſſel, if ſhe be only impell'd by her main maſt CD, her fore-part B will indifferently receive every motion of the bodies it meets ; for ſince the motion of the point C tends preciſely only to the carrying the point C forwards, it will only have its full effect upon the point B, when the ſaid point B is preciſely right before the point D, and conſequently will not hinder the point B from receiving from the waves, a motion carrying it either to the right or left. But if the point B is fix'd to a power, which will carry it right forward, it *Fig.* 18.

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* Our ſhips have but one triangular ſail bent to a yard, *viz.* the mizzen, which is ſhifted to leeward of the maſt every time the ſhip tacks, and can therefore be of no ill conſequence. But there are certain ſmall veſſels much uſed in the *Mediterranean*, which have only triangular ſails, as likewiſe have their gallies ; but ſtill in going about, they are always ſhifted to leeward of the maſt.

it will draw after it the reſt of the veſſel, and the water which ſtrikes againſt both its ſides, will keep the ſhip in equilibrium, and ſo overcome the motion which the waves would impreſs on the point B, which would otherwiſe throw her off to the right or left, and to this purpoſe the head ſails chiefly ſerve.

2. The head ſails, when brac'd ſharp to the wind, help a ſhip to ware. For let the *Fig.* 19. ſail AB inclined upon the end of the keel, receive the wind FD from abaſt, it will impreſs on the point D, a motion whoſe direction will be DE (by *Sup.* 2.) and which will conſequently be compoſed of two motions, the one carrying the point D right forward, and will be expreſs'd by the ſine DH, of the angle of the ſail with the keel; and the other carrying the point D ſideways, and thruſting it to leeward, with a force expreſſible by HE, the ſine of HDE, the complement of the angle of the ſail with the keel.

3. From whence it follows, that the more the head ſails are braced, the ſooner the veſſel wares, as having more force to flat her off; for in bracing the yard A of the ſail AB, 1. The angle of the wind upon the ſail is increaſed, *viz.* FDB, and conſequently the motion the ſail receives from the wind (by *Sup.* 8.) 2. The angle EDH is increaſed, and conſequently the force of the ſail to thruſt the point D to leeward (by the prec.) This rule is commonly found true in practice. Nevertheleſs the wind FD may ſo come from a-baſt, that in bracing in the lee-brace, the angle of the ſail with the wind, may be ſo diminiſhed, that the

ſail may loſe more of the force it receives from the wind by the diminution of the angle FDA than it acquires by the augmentation of the angle HDE, to make her ware. But this can only happen to ſuch ſails as may be ſo braced as to become nearly parallel with the keel.

4. If the wind DF take the ſail AB a-back, the veſſel will either fall off, or come to, according as the lines FD divide the angle of the ſail with the keel; that is, if the line FD divide the obtuſe angle of the ſail with the keel, ſhe will fall off; but if the line FD divide the acute angle of the ſail with the keel, ſhe will come to; in both caſes the ſine EH, of the complement of the angle BDH, meaſures the force of the ſail, either to flat her off, or bring her to.

Fig. 20.

5. In the firſt of theſe two caſes, it commonly happens, that the more the ſail is inclined with the keel, the more the angle of the wind with the ſail is augmented; and conſequently the more the ſail is inclined, the more force it has to make the ſhip fall off. But it is not the ſame in the ſecond caſe; for if the yard be too much brac'd in, the angle FDB of the wind with the ſail will be diminiſhed, and may become ſo acute, that the wind ſhall hardly have any force upon the ſail. It is therefore neceſſary, that the angle FDB be always greater than the angle EDH, ſince the force of the wind upon the ſail increaſes in a duplicate ratio of the ſines of the angles FDB; whereas the force of the ſail to bring the ſhip to the wind, increaſes only in proportion as the ſines of the angles EDH. In ſhort, it is eaſy to deter-

mine in all caſes, the meaſure of the angle FDB which ſhall have moſt power to bring a ſhip to the wind; ſince the product of the ſquare of the ſine of the angle FDB, by the ſine of the angle HDE, expreſſes the force of the ſail in bringing a ſhip to the wind, and conſequently the angle FDB will be moſt advantageous, when it makes that product greateſt. A table might eaſily be calculated for this purpoſe, if it be found uſeful in practice.

6. What has been ſaid of the head ſails, may be applied to the ſprit-ſail, which is ſtill more uſeful in flatting off, or wareing a ſhip, as it is farther remov'd from the ſhip's center of gravity, and is capable of being brac'd ſharper, as not being hinder'd by the ſhrouds: Its chief uſe being to keep the ſhip from ſheering backwards and forwards; for being very much inclined a-head, it greatly checks the riſing motion which the waves impreſs upon the head of the ſhip.

7. The fore ſail, and fore-top ſails being ſituated upon the end of the keel, have all the effects of the head ſails. 1. They hang ſomething forward, to prevent the veſſels ſheering. 2. The fore ſail is narroweſt at the bottom, that it may more eaſily be brac'd taught. 3. The fore ſail and fore-top ſails have but little force (the ſhip wareing) when their lee-braces are hal'd in cloſe, becauſe then the angle they make with the wind is very ſmall, though that which they make with the keel is large enough. 4. For which reaſon when they would ware expeditiouſly, they hale in the weather braces as cloſe as poſſible, which makes the ſhip immediately fall off; *for ſo they call this way of wareing, by lay-*

ing the head ſails a-back. 5. The fore ſail ſerv likewiſe to turn to windward, after the manner explain'd above. 6. The fore ſail and fore-top ſails may alſo, if laid a-back, bring up the ſhip to the wind, notwithſtanding they ſtand perpendicular to the keel. For let AB *Fig*. 21. repreſent a ſail perpendicular to the keel CD, and the courſe of the wind be CE, the ſail being thruſt by the wind CE, will force the veſſel back by the direction CD, (*Sup*. 3.) but as at the ſame time the wind will find better hold on the ſtern, it will conſequently puſh it to leeward, and make the ſhip loſe its equilibrium, the water too a-baft, having better hold on the windward ſide of the ſhip's counter, and puſhing it likewiſe to leeward, the veſſel will be in danger of turning quite round; to hinder which effect of the fore ſail, they put the helm a-lee, that ſo the water aſtern puſhing the rudder DF to windward, may reſiſt the wind which thruſts the ſtern D to leeward.

PROB. V.

Of the Main Sail.

1. The motion impreſs'd by the main ſail on a ſhip, tends directly only to move that part of the veſſel where the main maſt is fix'd, *viz*, its center of gravity, communicating to the other parts no more force than is neceſſary to move on the ſaid center of gravity in the direction of the ſail.

2. If the main ſail AB is thruſt forward in the direction CD parallel *Fig*. 22. to the keel, it ſhall impel the ſhip in the ſame direction, and the water ſtriking againſt

both ſides, ſhall keep her in equilibrium, and hinder her turning either to the right or left.

3. If the direction CD of the main ſail were perpendicular to the keel AB, the ſhip would by degrees range herſelf in that direction, and would bring her head A to the point D, for the water finding better hold on her ſtern B, than on her head A, will by degrees repel it behind the point C.

Fig. 23.

4. If the direction of the main ſail is oblique upon the keel, as CE; the ſhip will ſail in another direction between CD and CE, and make more head than ſide-way; becauſe the water ſtriking againſt her ſides, will keep her in equilibrium, and this oblique direction of the ſail will commonly hinder her turning either to the right or left. But ſtill this doth not hinder but that a ſhip only under a main ſail, may readily enough come to the wind; for the wind having great hold of the ſtern, will force her after-part to leeward, even with more force than is neceſſary to break the equilibrium.

Fig. 24.

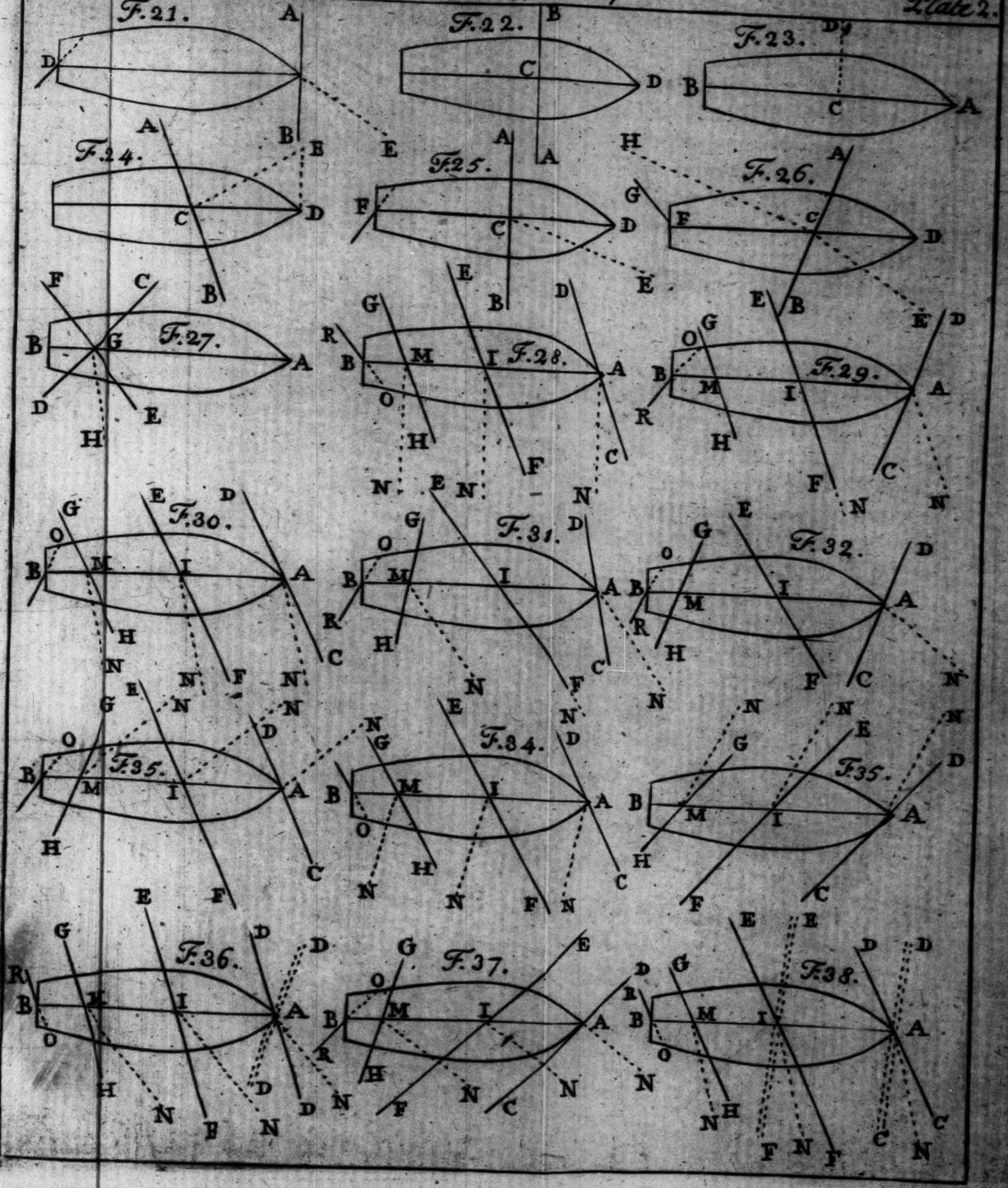
5, When the wind takes the main ſail A B a-back, in the line E C, the veſſel is thruſt in the direction CF, and the ſame thing will happen, as when the fore ſail is in the ſituation above explain'd.

Fig. 25.

6. If the main ſail AB being taken with the wind a-back in the line CE, is not perpendicular to the keel, but that its direction is ſome other line as CH, the ſhip will nearly keep the ſame direction; but the water thruſting up her ſtern againſt

The Working of a Ship

Plate 2.



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againſt the wind, will ſoon make her fall off, unleſs the rudder FG being put to leeward, overcomes the ſaid force of the water upon her ſtern. *Fig* 26.

PROP. VI.

Of the Mizzen.

1. The mizzen ſerves as the other ſails, to give the ſhip head-way; but its chief uſe is to bring the ſhip's head to the wind, by forcing her ſtern to leeward.

2. The triangular figure of the mizzen is well adapted to this deſign; 1. Becauſe it is eaſily hal'd up or out. 2. It preſents itſelf more effectually to the wind, as its yard is leſs flexible than a rope or ſtay. 3. The ſhrouds are no hindrance to it, but it may be eaſily inclined in any manner with the keel, inſomuch that it may be full when all the other ſails are a-back.

3. It is true, that triangular ſails deſign'd to give ſhips head-way, ought not to have the ſheet hal'd to windward, leſt the greateſt part of the ſail ſhould become a back ſail. But it is not ſo with the mizzen, whoſe chief uſe, as was ſaid, is to force the after-part of the ſhip to leeward, by a line perpendicular to the keel; for it has oftentimes more force to bring a ſhip to the wind with the ſheet to windward, than to leeward, as when the wind is far forward. For let AB repreſent the ſhip, and HG the wind, then ſhall the mizzen CD have more force to bring the ſhip to the wind, than the mizzen FE. However the making thus a back ſail of the mizzen, is ſeldom *Fig.* 27.

dom practiſed, except in ſome extraordinary caſes, becauſe it breaks the ſhip's head-way.

PROP. VII.

Of the other Sails.

The other ſails which are made uſe of beſides theſe already explain'd, as bonnets and ſtay-ſails, have nothing particular. It is only neceſſary to obſerve, that oftentimes the ſtay-ſails only ſerve to make a ſhip fall off, becauſe they are parallel to the keel, as when a ſhip ſails cloſe upon a wind.

PART II.

To turn a SHIP *any way.*

PROP. VIII.

To render a Ship ready to turn eaſily any way.

1. THE figure of a ſhip cauſing her naturally to preſent her head to the wind, makes it neceſſary to have a great proportion of ſail forward, for the more readily wareing her.

2. Notwithſtanding which, there are many veſſels too ready to come to the wind, and unapt to ware; which fault may proceed from ſeveral different cauſes: 1. Some have their ſterns too high built, and their poops ſerve as a ſail abaft. 2. Others have their fore-maſt ſet too far aft, which makes them leſs capable to reſiſt the force which ſo readily carries them to windward. 3. Others are built too ſharp a-head, which is remedied by thickning the bows.

3. If a ſhip be too backward in coming to the wind, the fault is to be corrected by ſome oppoſite means.

4. Great care ought to be taken, that the rudder be well proportioned to the ſhip, and that it be ſufficiently expoſed to the water that paſſes along the ſides of the veſſel.

5. When a ſhip is in a juſt equilibrium, and feels her helm as ſhe ought, it is ſtill no eaſy matter to keep her conſtant in her courſe, becauſe of the uncertainty of the waves and wind; it is therefore neceſſary to take the following precautions: 1. The range of the ſhip from her courſe, ought in the very beginning to be broke, which a light motion of the helm will then eaſily do. 2. When a ſhip is much yaw'd from her courſe, you muſt not bring her to it again at once, leſt you throw her into a contrary ſheer. 3. But if you ſhould be obliged ſo to do, you muſt eaſe the helm before ſhe be return'd to her courſe, to prevent the oppoſite ſheer, which elſe the force of her way will be apt to run her into.

Prop. IX.

To make a Ship fall off.

Fig. 28. Let the veſſel be AB, the head-ſails DC, thoſe of the main maſt EF, the mizzen GH, the line of the wind AN, IN, MN, the rudder BR, the tiller BO.

1. A veſſel is ſaid to ware, or fall off, when her head is thruſt to leeward, or her ſtern to the wind (*Def.* 6.)

2. When a veſſel has head way, the tiller is to be put over to windward, that the rudder BR may preſent itſelf to the current of water to leeward, and ſo puſh up the point B to the wind,

which cannot be done without making the head A fall off to leeward (*Prop.* 1.)

3. To ware the eaſier, hale up the mizzen, that ſo the line of the wind NM, which thruſts the ſtern to leeward, may not impede the impulſe of the rudder BR, in bringing up the ſtern to the wind.

4. Encreaſe the head-ſails, and brace them in as ſharp as poſſible to leeward, that they may have the more force to make the ſhip fall off. (*Prop.* 4.)

5. Hale up the main ſail, and ſhiver the main-top ſail, in order to eaſe the ſhip's way, which will facilitate her turning; but take heed you lay not the main-top ſail a-back, which would perhaps give her ſtern-way, and ſo bring her again to the wind, eſpecially as the rudder BR is to leeward.

6. Another way to ware a ſhip, is to brace in the head-ſails as much as poſſible, to windward, that the wind AN may have the greater power, and that their direction being leſs inclined upon the keel, they may have more force to thruſt the point A to leeward, and ſo make the veſſel fall off. But this method is not practiſed without an abſolute neceſſity, becauſe it very much hinders a ſhip's way; and when other ſhips are in company, puts her in danger of falling foul of thoſe which follow.

Fig. 29.

7. When this practice is made uſe of to avoid a danger, the main ſail and mizzen-top ſail may be laid a-back, in order to give the ſhip ſtern-way, and the helm ſhould be put over to leeward, that it

may not check her falling off. But ſkilful mariners take care not to ſhift the helm, before the ſhip begins to get ſtern-way.

Prop. X.

To bring a Ship to the Wind.

Fig. 30. To bring the ſhip AB to the wind, that is, to turn her head to windward, the following things are to be done.

1. Put over the tiller BO to leeward, that ſo the rudder BR meeting the current of water to windward, may force the ſtern B to leeward, which will conſequently bring the head A to the wind (*Prop.* 1.)

2. Hale out the mizzen GH, that the wind NM may force the ſtern M to leeward.

3. Diminiſh the head ſails by letting go the fore ſheet, and ſetting in the weather braces.

4. Make what ſail you can on the main maſt, that the ſhip having more way, may the better anſwer her helm; and that the wind may have more force upon the mizzen, and after-part of the ſhip. To explain myſelf,

The ſwifter the ſhip's motion is, 1. The water ſtrikes the ſtronger againſt the rudder. 2. It puſhes the ſtern of the ſhip with more force. 3. The wind has a greater effect upon the mizzen, and after-part of the veſſel, therefore the ſwiftneſs of a ſhip's motion helps the rudder every way in bringing her to the wind. But in falling off, as it helps on one hand, in ſtriking ſtronger againſt the rudder, ſo it hinders on the other hand, by its force on the mizzen, and ſtern of the ſhip, in puſhing her after-part to leeward.

PROP. XI.

To Tack with the Wind before the Beam.

To tack, is to turn a ſhip that is cloſe hal'd on one ſide, ſo that ſhe may be the ſame on the other. To tack therefore with the wind before the beam, is to turn a ſhip ſo that ſhe may ſtill take the wind before.

Let therefore AB repreſent a ſhip, which is to tack, 1. After having given her as much way as poſſible, right the helm, and hale out the mizzen; then when the veſſel begins to come to, put over the helm BO to leeward, and brace to the fore-top ſail, that the windward part of the ſail may lay a-back, which as before remark'd (*Prop.* 4. 3.) will help her to come to the wind.*

Fig. 30.

Fig. 31.

2. Eaſe a little the fore-bowlines to windward, and the fore-ſheets to leeward, that ſo the head ſails may loſe all power of making the ſhip fall off.

3. The mizzen may likewiſe be brac'd to leeward, that the wind NM may have the more force

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* The *Engliſh* practice in tacking is, as ſoon as the helm's a-lee, to let go the fore ſheet, and not lay the fore-top ſail a-back, till the ſhip is ſo far come up as to ſhake it; then laying it a-back, they tend it, and trim their after-ſails ſharp, not eaſing their fore-bowlines till they find the ſhip falls off too faſt.

to bring her to; but this is not done but in caſe of neceſſity, becauſe it deadens her way.

4. The head-ſails are not to be ſhifted, till the ſhip has paſs'd ſome degrees beyond the line of the wind, leſt the wind N A ſhould force back her head A, and hinder her coming to. *Fig.* 32.

5. For the ſame reaſon it is, that the bowlines and ſheets of the fore-ſails, are not entirely let go, leſt the ſails ſhould bag behind the maſt, and ſo force the ſhip's head to leeward.

6. When the ſhip is come enough about to ſhift the ſails; the mizzen ſhould be firſt ſet, that ſo the wind NM may break the way ſhe has in turning. *Fig.* 33.

7. In filling the ſails again, begin with the after-ones, if they cannot be all filled together; in order to make the moſt of the time in which the ſhip is falling off, to fill the head-ſails. In this caſe the main-ſail, as ſoon as it ſhivers, ſhould be immediately ſhifted.*

8. There is no fear that the wind AN, ſhould make the ſhip fall off too much, ſince the braces D being eas'd, and the main-ſail being ſet, will bring her up again to the wind.

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* Our way is always to brace about our after-ſails, and keep the head-ſails a-back till the after-ſails are full, and then brace about the head-ſails; for a ſhip in tacking is frequently caught, or comes back again, if the head-ſails are braced too ſoon.

9. 'Tis not eaſy to tack a ſhip, only with her top-ſails, when the ſea runs high, becauſe they do not give a ſhip way enough to overcome the ſwell which beats on her bow; the courſes are yet leſs ſufficient, as giving her ſtill leſs way, beſides that the fore-ſail when it takes a-back, makes too much of a bag to windward of the maſt, which will flat her off again.

10. If when a ſhip begins to come to the wind, her head-ſails are brac'd to, though not exactly perpendicular to her keel, ſhe will ſtay ſooner, but will fall more a-ſtern: On the contrary, if they are not brac'd, the ſhip will gain a-head in ſtaying, becauſe the force of her way will ſuſtain her againſt any contrary impulſe impreſs'd on her by thoſe ſails a-back; therefore when a ſhip is lively enough to ſtay, the head-ſails are not brac'd to at all.

PROP. XII.

To change the Board with the Wind a-baſt the Beam.

Suppoſe the veſſel AB, were obliged to change her board with the wind a-baſt the beam, either becauſe ſhe cannot bring the wind forward, or that for ſome particular reaſon ſhe is obliged to change her board with the wind a-baſt the beam, and to take luff for luff. *Fig.* 34.

1. Hale up the mizzen, and put over the tiller OB to windward, then when the veſſel has got lee-way, bring to the weather braces, and in proportion as ſhe falls off, continue to brace in, that

ſe when the ſhip comes right into the direction of the wind, the ſails may ſtand trim'd right before it.

2. When the ſhip's way has brought her beyond the line of the wind, hale out the mizzen, that ſo with the rudder, which will then ſtand right for bringing her to the wind, it may continue to help the veſſel to turn; continue likewiſe to brace in the ſails, till they are brought cloſe upon the wind. Then haling up again the mizzen, ſhift the helm to break the force of her way to windward.

3. If when the mizzen is hal'd up, and the helm ſhifted, ſhe does not fall off; it may be effected by bracing in the ſails as cloſe as poſſible to windward. But as ſoon as ever the ſhip begins to get lee-way, right the ſails again to help her, leſt when ſhe comes near the line of the wind, the wind NA ſhould break the ſhip's way in turning. *Fig.* 35.

4. Take care not to be too haſty in bracing the ſails, when the ſhip begins to fall off, leſt by ſome ſudden motion the wind ſhould take the ſails a-back.

Prop. XIII.

To prevent the Accident, call'd building a Chapel.

A Ship is ſaid to build a chapel, when the wind, taking her a head, forces her unexpectedly about. This accident is dangerous, becauſe it may throw a ſhip in the way of another a-ſtern of her, or upon other dangers.

Fig. 36.

1. Suppoſe the ſhip A B, take the wind a head, if ſhe remains in that diſpoſition, the wind NA falling upon the ſail CD, will make the ſhip come to the wind till ſhe paſſes the line of the wind, when ſtriking her with ſtill greater force, it will bring her ſtern to windward. To hinder which, put the helm over to windward, hale up the mizzen, and brace the head-ſails DC to the wind, till the angle CAB becomes a little acute; that ſo the wind NA falling upon the ſail DC, may thruſt back the head A to leeward, and make the veſſel fall off. Then when the ſhip has got lee-way, right the ſails DC again, and hale out the mizzen, putting over the helm too to leeward, to prevent her falling off too much.

2. If the angle CAB be made very acute, the ſhip will fall off ſooner, and force her leſs a-ſtern. But then it may happen, that the ſhip has already turn'd ſo far that the ſails DC may ſhiver, or even fill, which will render it impoſſible to prevent the accident. 'Tis therefore proper to brace the ſails CD no more than is juſt neceſſary to flat the ſhip off.

Fig. 37.

3. Suppoſe the ſhip AB has all its ſails a-back, in order to fall a-ſtern, if after ſhe has loſt her head-way, the helm BO be put over to leeward, the water which ſtrikes againſt the rudder when the ſhip begins to get ſtern-way, will throw up her ſtern B to the wind, and the wind NA will fling her head to leeward with ſo much force, that nothing can ſtop her turning about. But this accident may eaſily be prevented, by bracing a little the ſails DC to the wind, that is, by making the angle CAB a little acute,

and putting the helm and mizzen to bring her to the wind. Nor need it be feared that the veſſel ſhould come too much to the wind; for the ſails CD will receive the wind NA more perpendicularly, as the ſhip gains to windward, and force her with the greater ſtrength to leeward.

4. Many ſkilſul ſeamen make uſe of this practice when they ſound, becauſe the ſhip then makes little or no way, and is not at all liable to build a chapel.

Prop. XIV.

To lye to under the Top-ſails.

A ſhip is ſaid to lye to, when her ſails are ſo diſpoſed, that producing contrary effects the one to the other, they render the ſhip as it were immoveable.

Fig. 38. 1. Let AB repreſent a ſhip, whoſe ſails are ſo diſpoſed, that the angles CAB, FAB, may be ſomewhat acute, the mizzen GH being hal'd out, and the rudder BR to leeward. In this ſituation, the head-ſails will puſh the ſhip's head A, by the line NA, to leeward; and the after-ſails GH, bearing her ſtern to leeward, by the line NM, will force up her head to windward: So likewiſe the ſails DC, EF thruſting the ſhip a-ſtern, and the ſails HG bearing up a little a-head, conſequently as the ſhip cannot eaſily divide the water a-ſtern, ſhe will remain almoſt immoveable, making but very little way, and that a-ſtern; for which reaſon the effect of the rudder BR will be to bring up the ſhip a little to the wind.

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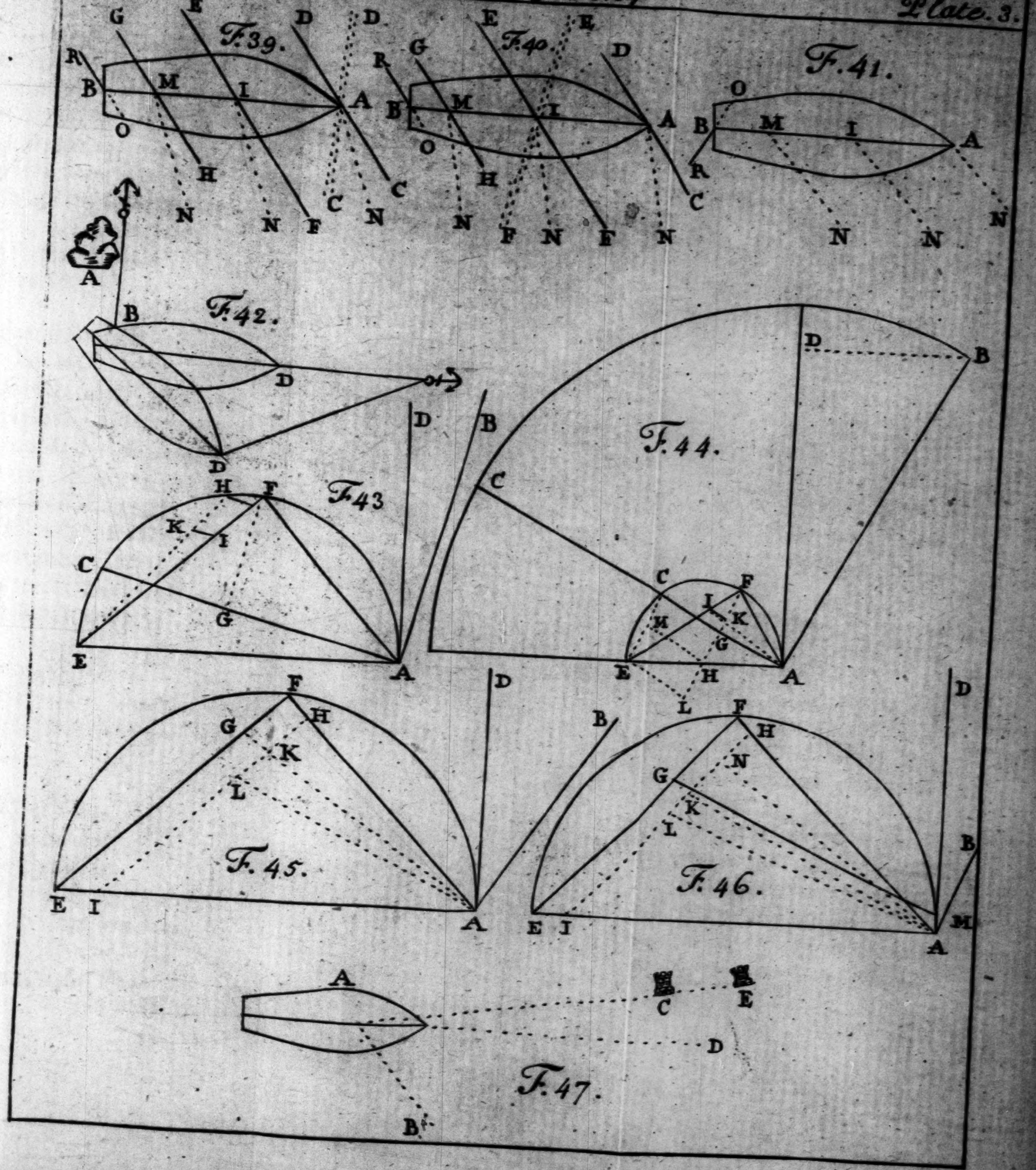
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2. The lower ſails being furl'd and the top-ſails a little lower'd, brace in the fore-top ſail DC, till the angle CAB becomes a little acute, gaining a little at the ſame time to windward, that the fore-top ſail may be taken a-back, whilſt the main-top ſail is fill'd by bracing it in to leeward. In this ſituation the ſhip is thruſt a-head, and to windward by the main-top ſail, (*Prop.* 5. 4.) and a-ſtern, and to leeward by the fore-top ſail (*Prop.* 4. 2.) ſo that between both, ſhe remains as it were immoveable. *Fig.* 39.

3. If in this diſpoſition the ſhip falls off too much, hale out the mizzen, or make uſe of the mizzen-top ſail, and if notwithſtanding all that, ſhe ſtill falls off, make the angle CAB leſs acute, and the angle CAN more acute, by bracing in the fore-top ſail a little to leeward. There is no fear of her coming too much to the wind, becauſe as ſhe comes to windward, the ſail DC will take the wind more directly, which will give it more power to flat her off. Thus a ſhip lies to moſt ſafely under a mizzen; but then ſhe is moſt liable to fall off.

4. The helm ought for the moſt part to be put over to leeward, ſince the veſſel more commonly falls a-ſtern than gains a-head; for both the hull and rigging ſerve as a back ſail.

5. A ſhip may lye to, with her fore-top ſail DC fill'd, and her main-top ſail EF a-back; and in this diſpoſition ſhe will not ſo eaſily fall off, becauſe the ſail DC keeps her cloſer to the wind, and has leſs force to flat her off. (*Prop.* 4. 3.) 2. The ſail EF has more power to bring her to the wind (*Prop.* 5. 5.) *Fig.* 40.

Therefore this way of lying to, ſeems the moſt convenient for a fleet in a line of battle; but as it puts a ſhip in greater danger of taking the wind a-head, it is ſeldom uſed but in engagements, when it is of much more conſequence not to fall to leeward, than to prevent the accident of taking the wind a-head.

PROP. XV.

To lye to under the Courſes.

When on account of the violence of the wind, or the fear of danger, or of any other reaſon, it is thought convenient to lye by: If then the ſhip cannot come to an anchor, nor lye to under her top-ſails, they then try under her courſes; that is (as before with her top-ſails) they ſo diſpoſe her lower ſails, that ſhe may make little or no way.

1. The top-ſails being furl'd, and the lower ſails trim'd cloſe, keep as near the wind as poſſible, without hazard of taking the wind a-head, that ſo the ſhip may make very little head-way, and only fall off in a line between the direction of the wind and the rumb of the courſe.

2. A ſhip will ſtill make leſs way, if the main ſail be likewiſe furl'd, and only the fore-ſail and mizzen ſet, or the mizzen alone.

3. Sometimes the main-ſail only is made uſe of, and then the ſhip will move only by jerks as it were, and fall too near the line of the wind. She will thus make but little way, but then ſhe will labour very much. The rudder will be but of little ſervice in this caſe; but that the ſhip may labour the leſs, let the helm be ſo put to leeward, that the rudder may be nearly parallel to her courſe.

4. Sometimes the wind blows ſo hard, that a ſhip cannot bear any ſail. In ſuch caſe, having furl'd all the ſails, and ſquar'd the lower yards, brace the top-ſail yards in the ſame manner as if the ſails were ſpread, and put the helm hard over to leeward. Thus ſhall the ſhip move as it were by jerks, moſt commonly preſenting her ſide to the wind, becauſe when ſhe is pretty much fallen off, ſhe gets head-way, and the rudder BR will bring her again to the wind, and when ſhe has gain'd too much to windward, ſhe will fall a-ſtern, and the rudder BR will again throw her to leeward. If the helm be put over to windward, the rudder will bring the ſhip about, ſince if ſhe be much fallen off, and has got head-way, the rudder will make her fall ſtill more off; and if ſhe comes too cloſe to the wind, and falls a-ſtern, the rudder will ſtill bring her more to windward. From whence it follows, that by means of the rudder a ſhip may be turn'd, though ſhe has not a ſingle ſail ſpread. *Fig.* 41.

5. If when a veſſel is thus only driving with her maſts and yards, it is thought proper to let her go before the wind, when the ſhip comes into the line of the wind, right the helm, and manage it altogether the ſameas if the veſſel were under ſail, for, in ſuch hard gales eſpecially, the hull and rigging are in effect a ſail. And thus driving before the wind, a ſhip will ſometimes make ſuch great way, that ſhe may run much hazard of being loſt, if ſhe hath not ſufficient ſea room.

PROP. XVI.

To govern a Ship with the Yards.

1. It is eaſy to govern a ſhip with the ſails, ſince ſome of them ſerve to make her fall off, and

others to bring her to the wind; and ſince the yards ſerve in ſome degree as ſails, a ſhip may in like manner be govern'd with her yards.

2. When in fine weather it is thought convenient to change the place of a ſhip's riding, in a road where there are many other veſſels; unfurl the mizzen, and mizzen-top ſail, and in weighing the anchor, let the yards be brac'd as much as poſſible oppoſite to the place where the ſhip is to fall. Then when the anchor is up, and the ſhip ſufficiently fallen off to take the proper direction, ſet the yards in all reſpects as if the ſails were ſpread; if the ſhip comes too much to the wind, hale up the mizzen, and brace the fore yards cloſe in to windward. If ſhe falls off too much, hale out the mizzen and mizzen-top ſail. If the ſhip has too much head-way, check her by laying the mizzen-top ſail aback. If ſhe has too little head-way, increaſe it by aſſiſtance of the mizzen and mizzen-top ſail. In this manner you may traverſe a road as you pleaſe, and moor a ſhip juſt where you have a mind. But for the greater ſecurity, they commonly ſend out a boat with a ſmall anchor, in caſe of a calm or a contrary wind.

REMARK.

Many other common practices in the working of a ſhip might be added to theſe above explain'd; but as they have nothing particular to be accounted for, I ſhall paſs them over, that I may not tire my reader with tedious repetitions.

PART III.

Of ſailing from one Place to another at a diſtance.

PROP. XVII.

To come to ſail.

1. AT a proper time to go to ſea, having unmoor'd your ſhip, in heaving up to your other anchor, ſteer your ſhip right with the anchor, and having recover'd the buoy and brought your ſhip a-peek, looſe your top ſails, and ſet them, bracing the main-yard and main-top ſail up ſharp, and your fore-top ſail a-back, to flat her off to that ſide you would caſt her; at the ſame time haling out the mizzen to bring her the more readily to again; in this manner if you have nothing to oblige you to make ſail, keep her till your anchor is ſtow'd, when you may ware her to her courſe, and then make uſe of what ſails you think proper.

2. If in bad weather you are oblig'd to come to ſail, and in doing it, are in danger of falling upon ſome rock as A, carry out a ſmall anchor on that bow your danger lies, and bring the hawſer in a-baſt on the ſame quarter, *Fig.* 42.

and make him faſt, which having done, vere away the cable D, till the ſhip is fallen off ſo far as that you may ſerve yourſelf with ſuch ſails as are proper for the weather, which, when you can do, cut away your cable and hawſer.

3. If time and weather will permit, it would be better to carry an anchor farther out a head, after having hove in as much as may be on the anchor down, and come to ſail from the anchor ſo carried out, from whence you will probably have room to caſt.

4. When the weather permits you not to come to ſail with the top-ſails, you may with the fore-ſail and mizzen.

5. When you are obliged to cut, in order the more readily to come to ſail, be ſure you do it not till your top-ſails are hoiſted, and brac'd for caſting, leſt you fall to leeward, and loſe more time than if you had hove up your anchor. Remember alſo to leave a buoy on the end of the cable, that you may take it up again if opportunity offers.

PROP. XVIII.

Of gaining as much as may be to windward.

1. If a ſhip had as much difficulty to divide the water with her head, as with her ſides, as would be the caſe were ſhe round, ſhe could then no way gain to windward. For let the ſhip be A, the line of the wind BA, the perpendicular to the wind CA, the ſail DA, its direction AE. If the veſſel A were round, ſhe would continually keep the direction AE of the *Fig.* 43.

ſail, and conſequently fall off from the line AC; which is called falling to leeward or making lee-way (*Def.* 4.)

2. If on the contrary, a ſhip could not at all divide the water with her ſides; but always kept the line ſhe looks in, without making any lee-way, ſhe would continually gain to windward when ſhe looks above the line AC, as in the line AF, and what ſhe gains to windward will be meaſur'd by FG, the ſine of the angle FAG, provided her abſolute motion be meaſured by the line FA. That is to ſay, the product of the ſine of the angle FAG by the ſine of the angle FEA, or FAD, will always be what the ſhip gains to windward in the courſe FA. But this product will always be greateſt when the two ſines are equal; therefore the ſhip A will always gain moſt to windward when the line FA divides the angles CAD into two equal parts.

Or, if you like better ſo to expreſs it, the point F in the middle of the arch AFC, is the moſt diſtant point from AC, or more to windward than any other point as H, in the ſame arch; and moreover the ſhip will arrive as ſoon at the point F, as at the point H. (*Prop.* 2. 7.) Therefore ſhe will gain moſt to windward, when her courſe AF equally divides the arch AFC, or the angle DAC.

3. Lee-way makes no alteration in this rule; for if a ſhip making lee-way, ſhall only arrive at the point I, in the line FE, in looking up to the point F; in looking up to the point H, ſhe ſhall only reach the point K, of the line HE; and the lines FH, IK, ſhall be parallel (by *Prop.* 1. 7.) Therefore

fore if F is to windward of H, I ſhall be to windward of K (by *Def.* 4.)

4. Let us go on ſuppoſing the ſhip to make no lee-way; draw B D the ſine of the angle B A D, which the ſituation of the ſail makes with the wind. Since the ſines DB are to one another, as the roots of the impulſions of the wind upon the ſail (by *Sup.* 8.) in its different ſituations; and that the different velocities of a ſhip's ſailing are alſo to one another, as the roots of the ſame impulſions (by *Sup.* 7.) the different velocities of ſailing ſhall be to one another, in different ſituations of the ſail, as the ſine DB; and conſequently the velocity of a ſhip may always be expreſs'd by the ſine DB, in ſuppoſing the ſine total to expreſs the velocity of a ſhip ſailing before the wind. Make then AE equal to DB; and having deſcrib'd the ſemicircle ACE; from the center H draw HF perpendicular to AC, which ſhall divide the arch AFC equally in the point F (by *Eucl.* 1. 3.) and cut the line AC in the point G. But the line AF is the moſt advantageous courſe for the ſhip to gain to windward in the ſituation of the ſail DAB (by the prec.) therefore the line FG ſhall be all that the ſhip is able to gain to windward in the ſituation DAB. Upon which we may make the following reflections:

Fig. 44.

1. If the angle DAB is juſt 30 degrees, FG ſhall be exactly $\frac{1}{8}$ of radius.

Demonſt. DB, or AE being the ſine of 30 degrees, will be $\frac{1}{2}$ the radius, and ſince all the angles of the triangles HAF are of 60 degrees, FA will be equal to AH, or $\frac{1}{4}$ of radius. But FG being the ſine of 30 degrees, will be the half of AF; it will therefore be $\frac{1}{8}$ of radius.

2. If the angle DAB be more than 30 degrees, FG will be leſs than $\frac{1}{8}$ of radius. Let us call *d* the difference between the ſine of 30 degrees, and the ſine DB, which we ſuppoſe greater.

Demonſt. AE being equal to $\frac{1}{2}$ radius with *d*, and conſequently HF being equal to $\frac{1}{4}$ of radius, and $\frac{1}{2}$ *d*. Moreover HG being the ſine of above 30 degrees, will be equal to the $\frac{1}{2}$ of HA, or $\frac{1}{8}$ of radius, and $\frac{1}{4}$ of *d*, and beſides of a magnitude which will be to *d*, as AH to the ſine total, or more than its fourth; therefore HG ſhall be more than $\frac{1}{8}$ of radius, and $\frac{2}{4}$ of *d*, and conſequently if it be ſubſtracted from HF, the remainder FG will be leſs than $\frac{1}{8}$ of radius.

3. If the angle DAB be leſs than 30 degrees, FG will be leſs than $\frac{1}{8}$ of radius. Let us again call *d* the difference between the ſine of 30 degrees, and the ſine DB which we ſuppoſe leſs.

Demonſt. HF will be $\frac{1}{4}$ of radius leſs $\frac{1}{2}$ *d*. Moreover HG will be $\frac{1}{2}$ of AH leſs a magnitude, which will be to *d* as HA to radius; that is to ſay, leſs than its fourth; therefore AG will be equal to more than the $\frac{1}{2}$ of AH leſs $\frac{1}{4}$ of *d*, or will be equal to more than $\frac{1}{8}$ of radius, leſs $\frac{2}{4}$ of *d*, and conſequently if it be ſubtracted from FH, the remainder will be leſs than $\frac{1}{8}$ of radius.

COROLLARY.

From whence it follows, that if the ſhip makes no lee-way, the ſituation DAB, the moſt advantageous to gain to windward, ought to be juſt 30 degrees.

5. To find what alteration *lee-way* will make in this rule. Draw EL, and HM, parallel to CA, and continue FG, till it meets EL, in the point L. Again, draw CE, in proportion to EA, as DB to BA. Then ſuppoſing EI to FE, as the difficulty of the ſhip's dividing the water by her head, to that of dividing it by her ſide; and as any magnitude *d* (which we call *lee-way*) is to the ſine total. Laſtly, ſuppoſing IK parallel to CA; in the ſituation DAB of the ſail with the wind, the line FG leſs FK, will be what the ſhip gains to windward; knowing therefore FK, her advance to windward may be known; for FG is eaſily known as above explain'd. Thus therefore may be found FK. Since the angle CAE is equal to the angle DAB; the ſine total AB, is to DB, as AE equal to DB, is to CE, which by this means will be known; and conſequently GH may be found, which is the half of CE; this added to the half of AE gives FL. Therefore ſince EF : EI : : LF : LK, FK is conſequently diſcovered.

COROLLARY.

As it may be known what a ſhip gains to windward in every ſituation of the ſail, it will be found that the moſt advantageous ſituation for that purpoſe, is when it makes the ſine DB, equal to half the radius, leſs a magnitude or quantity, which is to the ſine total, as the lee-way *d*, is to the ſine total more the lee-way *d*. For in augmenting or diminiſhing ever ſo little this ſituation, GK will be found leſs.

LEMMA.

If A being greater than B, does not exceed it more than B does C; the ſquare of B ſhall be greater than the product of A into C (by *Eucl.* 16. 6.) Since A will have a leſſer ratio to B, than B to C.

PROP. XIX.

To find the moſt advantageous ſituation of a Sail for a Courſe given, when a ſhip makes no lee-way.

1. Let AB be the line of the wind, AF the courſe, and DA the ſail: Draw AE perpendicular to the ſail, and equal to the ſine of the angle DAB, and upon AE deſcribe a ſemi-circle cutting the courſe AF, in the point F, ſo ſhall AF be the velocity of the ſhip, in the ſituation of the ſail DAB. *Fig.* 45.

2. The angle FEA being equal to the angle FAD; the ſine total will always be to the line AE the ſine of the angle DAB, as the ſine of the angle FAD, to the line AF; and conſequently, the product of the ſine DAB by the ſine FAD, being divided by the ſine total, will give the velocity AF.

3. This product will always be greateſt when the two angles DEB, FAD are equal (by *Lem. prec.*) ſince in augmenting the one, its ſine is only increaſed, in proportion as the other is diminiſhed; ſo that the velocity of the ſhip is always greateſt, when the ſail AD divides the angle FAB of the courſe with the wind, into two equal parts.

REMARK.

This rule then ſerves for gaining the moſt that may be to windward in a given courſe, when a ſhip is ſuppoſed to make no lee-way; becauſe in that caſe to go moſt ſwift, is the ſame thing as to gain moſt to windward. This rule therefore is of great ſervice in practice, ſince lee-way is very often inſenſible,

Prop. XX.

Of the alteration in Velocity, which lee-way will cauſe in the foregoing Propoſition.

Fig. 45.

1. If AF be the rumb line upon which the ſhip ought to ſail, the ſail ſhall be ſtill in the moſt advantageous ſituation for velocity upon ſuch rumb, when it equally divides the angle FAB.

Demonſt. Let us ſuppoſe the ſail to divide the angle FAB unequally, then if the veſſel having no lee-way, would arrive but at the point H, in the time ſhe would have got to the point F; (by the prec.) with lee-way ſhe will only obtain the point K of the perpendicular HI, in the time ſhe would have come to the point G of the perpendicular FE.

2. If the ſhip keeping the rumb AF, is carried by her lee-way to the point G of the perpendicular FE, when the ſail equally divides the angle FAB the angle DAB cannot be augmented without re tarding the ſhip's arrival at the point G.

Demonſt. If the angle DAB be augmented, an the ſhip keeps the ſame rumb AF, ſhe will com but to the line HI, in the time ſhe would have g to the line FE; but as her lee-way would carr her on in a line below the line AG, it is therefo neceſſary ſhe ſhould run more to windward, f which reaſon at the time ſhe ſhould have gain'd t line FE, ſhe will be found in a line ſtill nearer t poi point A, than the line HI, and conſequently will only arrive at ſome point nearer A, than the point K, at the time ſhe ſhould have arrived at the point G.

3. If the angle DAB be diminiſhed, the ſhip will then ſooner arrive at the point G, and it will be eaſy to find the velocity AG in every poſition of the ſail. For the ſine total will always be to the ſine of the angle DAB; as the ſine of the angle FAE the complement of FAD, to FE; therefore F E may be known, and conſequently F G, which is to FE, as the lee-way, to the ſine total. Farther, the angle GAF may be known; for the tangent of the angle EAF, is to the tangent of the angle GAF, as EF to GF. Laſtly, AG may be found; for the ſine of the angle GAF, is to GF, as the ſine total to AG.

COROLLARY.

The angle DAB, which ſhall be the moſt advantageous, may be found by a trigonometrical calculation, that is, ſuch an angle as cannot be augmented or diminiſhed, without leſſening AG. For example, ſuppoſe it were required to find the moſt advantageous ſituation of the ſail for a ſhip, whoſe lee-way is to the ſine total, as 1 to 10, and is to keep the courſe AG, making an angle GAB with the wind of 100 degrees. I begin by ſuppoſing that the angle DAF ought to be 51 degrees, that is a little more than half the angle GAB. Its complement FAE will be 39 degrees, ſubtract the logarithm of 10 from the logarithm of the tangent of 39 degrees, and the remainder will be the logarithm of the tangent of the angle GAF, which will be 4 degrees 38′; this added to the angle FAD, gives 55° 38′ for the angle GAD; and conſequently the angle DAB will be 44° 22′. Add the logarithm of 44° 22′ to the logarithm of 39° and from the ſum ſubtract the logarithm of the ſine total, the remainder will be the logarithm of FE, from which muſt be taken the logarithm of 10 to get the logarithm of FG. Then adding the logarithm of the ſine total to that of FG, and ſubſtracting from the ſum the logarithm of the angle GAF, the remainder will be the logarithm of the velocity GA, for the ſituation which makes the angle DAB 44° 22.

9.908369	Log. *Tan.* 39 degrees
1.009000	Log. 10
8.908369	Log. *Tan.* 4 deg. 38′
9.79887	Log. *Sine* 39 degrees
9.84463	Log. *Sine* 44 deg. 22′
19.64350	
10.00000	
9.64350	Log. FE
1 00000	
8.64350	Log. FG
10.00000	
18.64350	
8.90692	Log. 4 deg. 38′
9.73658	Log. AG

Do the ſame in augmenting, or diminiſhing the angle DAF till it cannot be more increas'd or diminiſhed, without leſſening the velocity AG, and you will obtain the moſt advantageous ſituation.

After this manner the following table is made, and ſo may be calculated for every poſſible caſe.

A Tabl

A Table of the Situation of the Sail for the ſeveral Courſes therein given.

Angle of the Wind with the Courſe given	Lee-way $\frac{1}{5}$		$\frac{1}{10}$		$\frac{1}{20}$	
	Angle of the Wind with the Courſe to be kept	Angle of the Wind with the Sail	Angle of the Wind with the Courſe to be kept	Angle of the Wind with the Sail	Angle of the Wind with the Courſe to be kept	Angle of the Wind with the Sail
Degr.	Degrees	Degr.	Degrees	Degr.	Degrees	Degr.
170	169	84	170	85	170	85
160	158	79	159	79	160	80
150	147	73	148	74	149	74
140	135	66	138	67	139	69
130	124	60	127	62	129	64
120	113	54	117	57	118	58
110	102	48	106	51	108	52
100	90	41	95	45	98	47
90	79	33	84	39	87	41
80	67	26	73	34	77	35
70	55	18	62	27	66	31

PROP. XXI.

Of the alteration which Lee-way will make in the forgoing Propoſitions, when a ſhip is to gain more to windward.

1. If the courſe be determined, there will be no alteration in the laſt propoſition.

2. If only the rumb line AF be determined, the angle DAB muſt not be greater than half the angle FAB. *Fig.* 46.

Demonſt. The angle DAB being above the half of FAB, the ſhip would only gain the point L, in the time ſhe ſhould have got to the point G, if the angle DAB had been but half the angle FAB (by the prec.) which point G, muſt always be to windward of the point L, ſince if it be required to gain to windward, the angle FAB muſt be acute.

3. In making the angle DAB leſs than half of FAB, the ſhip will gain to windward, ſince the angle of the lee-way becoming leſs, the ſhip may arrive at the point N, in the time ſhe would have come to G, if the angle DAB had been half of FAB.

4. It is eaſy to determine what a ſhip gains to windward upon every ſituation of the ſail; for having drawn the perpendicular GM upon AB, the line MA will be the ſhip's gain to windward; and the ſine total will always be to AG, as the ſine of the angle MGA the complement of GAB, to the line AM.

Coral. The moſt advantageous ſituation of the ſail for gaining to windward, may therefore be alſo found, and thrown into tables ſerving every poſſible caſe, as in that which follows.

A Table of the Situation of the Sail for gaining to Windward upon the ſeveral Rumb Lines therein given.

Lee-way	$\frac{1}{5}$	$\frac{1}{10}$	$\frac{1}{20}$
Angle of the given Rumb with the Wind	Angle of the Sail with the Wind	Angle of the Sail with the Wind	Angle of the Sail with the Wind
Degrees	Degrees	Degrees	Degrees
85	0	19	19
80	16	20	24
75	18	21	33
70	20	23	31
65	23	26	30
60	22	25	26

Prop. XXII.

To find the proper Rumb a ſhip ſhould keep, in ſailing from one fix'd Place to another.

1. If the veſſel has no lee-way, let her head point directly to the place ſhe is to ſail to.

2. When a ſhip has lee-way, turn her head to windward of the point ſhe is to make, in the following manner. Suppoſe the ſhip A, the line of the wind BA, the point ſhe is to ſail to, C; then muſt the ſhip range upon ſome other line, as AD, and there will be two ways of obſerving whether ſhe makes too much or too little to windward. 1. Take notice of ſome object as E, which anſwers directly with the point C, and if when the ſhip has ſailed ſome length, the object ſtill continues to anſwer directly with the point C, it is plain the ſhip keeps the line ACE, and will run directly upon the point C. But if after ſome time ſailing, the object E opens to windward of the point C, you may be ſure the ſhip's head points too much to windward, and that the ſhip will run to windward of the point C, unleſs ſhe falls off a little. If the object E opens to leeward of the point C, then 'tis certain the ſhip falls off too much, and will not weather the point C. 2. Set the point C by the compaſs, and if after ſome time ſailing, the point C continues to bear the ſame, the ſhip then keeps the right courſe; but if the point C falls to lee-ward, the ſhip runs too much to windward; on the contrary, if the point

Fig. 47.

point C appears more to windward, the ſhip then falls off too much.

3. In the ſame manner it may be known whether a ſhip will double a cape; or whether ſhe will gain to windward, or fall to leeward of another ſhip riding at anchor, *&c.*

PROP. XXIII.

To find the proper Courſe for chaſing a Veſſel to Leeward.

Suppoſe the ſhip A were to chaſe the ſhip B, and FA the line of the wind. *Fig.* 48.

1. If the ſhip A were to bear right down upon the ſhip B, ſhe would deſcribe, in approaching her, a curve line, till ſhe falls into her wake, and would run a hazard of not coming up with her at all; both as ſhe would have more way to run, and would loſe the advantage of the wind.

2. The ſhip A muſt then look to windward of the ſhip B, and range upon ſome line as AE, wherein ſhe may come up with the ſhip B at the point E. But to know that line, it muſt be conſidered, that if the veſſel A comes up with the veſſel B at the point E, ſhe muſt run through the line AE, in the ſame time that the veſſel B is running through the line BE; and conſequently imagining the lines CD parallels to AB, to cut the lines AE, and BE, into proportional Parts, (by 2. 6. of *Eucl.*) the two ſhips will arrive at the ſame time upon each of theſe parallels, and conſequently with regard to each other, will con-

tinue

tinue on the ſame rumb, as when they were on the line AB.

3. It is then eaſy to know, if the line AE, upon which the ſhip A ranges, is a proper courſe for meeting the ſhip B at the point E, by repeatedly ſetting the ſhip B by the compaſs, at little intervals of time. For if the ſame bearing continues, it is a certain ſign the two ſhips arrive at the ſame time upon each of the lines CD, and will conſequently meet at E; but if after ſome time, the ſhip B falls to leeward, it may be concluded that the ſhip A keeps too much to windward; on the contrary, if the ſhip B is found more to windward, after having made a ſmall run, it ſhews that the ſhip A falls off too much, and muſt keep cloſer to the wind, not to fall to leeward of the ſhip B.

REMARKS.

1. Though the ſhips A and B ſail equally well, yet if the ſhip B continues ſailing cloſe upon the wind in the line EE, the ſhip A, which is to windward, may come up with her by ſome other line as AE. Since the ſhip A ſailing with a larger wind will run ſwifter, and may therefore run through the lines AC, while the ſhip B is running thro' the lines BD.

2. In like manner the ſhip A may come up with the ſhip B, by many different lines, if in falling off, ſhe increaſes her velocity in the ſame ratio as the lines AC.

PROP.

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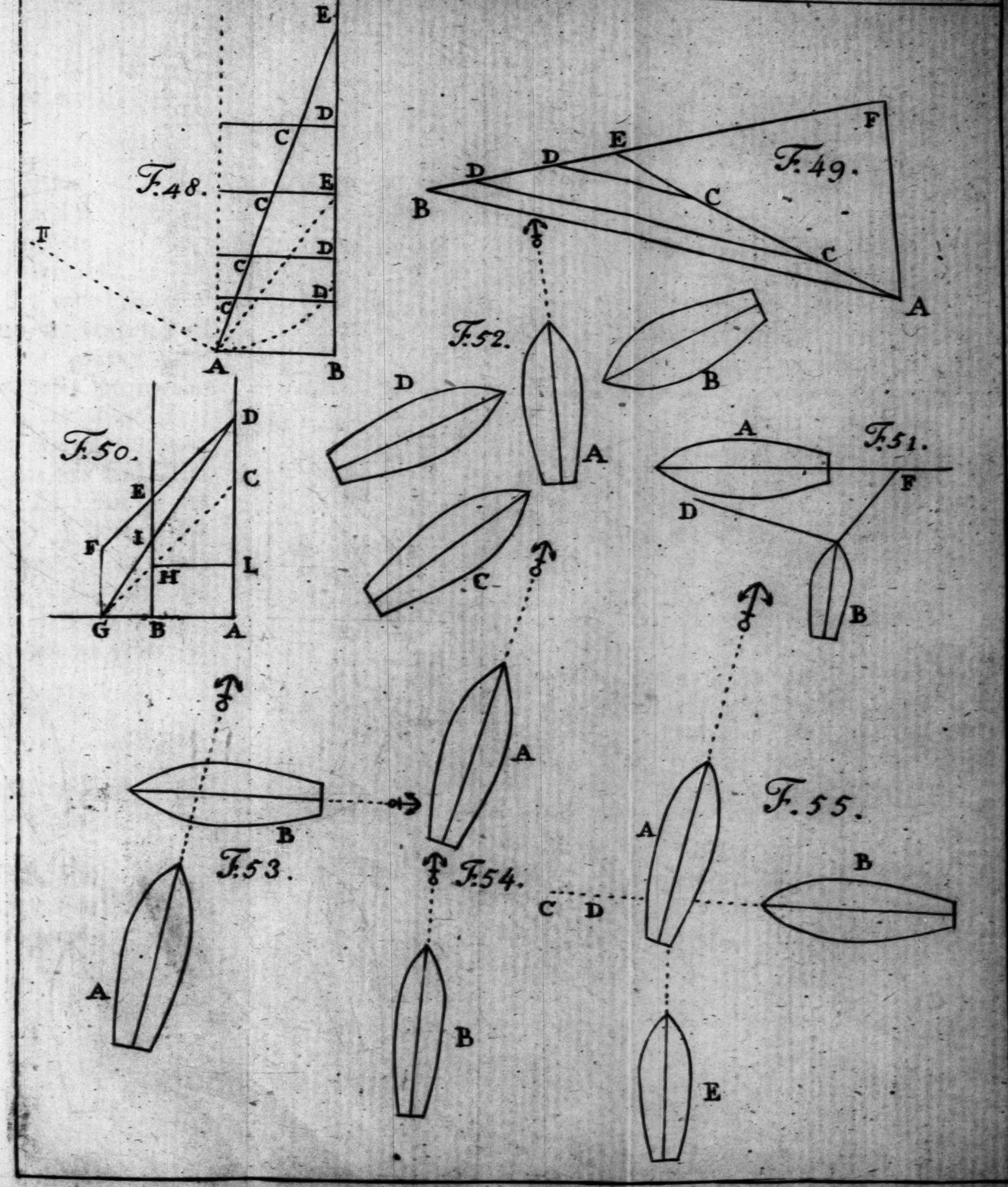
PROP.

The Working of a Ship *Plate 4.*



PROP. XXIV.

To find the proper Courſe for a Ship to cut, or croſs the Way of another, to windward of her.

1. The ſhip A being to leeward of the ſhip B, may poſſibly be ſo good a ſailer, that in tacking on any line as AE, ſhe may run through the parts AC, while the ſhip B is running through the correſpondent parts BD, and conſequently come up with her at the point E. Whether AE be the proper line, may be tried as before, by frequently ſetting the ſhip B by the compaſs; for if ſhe be found ſtill to bear upon the ſame point, it ſhews the two ſhips anſwer each other by the parallels CD, and that they will meet at the point E. But if the ſhip B falls to leeward, the ſhip A keeps too much of the wind; on the contrary, if the ſhip B gains to windward, the ſhip A falls off too much; and therefore if ſhe can lay no nearer, ſhe will not be at all able to cut or croſs the way of the ſhip B. *Fig.* 49.

PROP. XXV.

To find the Point where a Ship ought to Tack, to cut or croſs another to windward of her.

1. If the two ſhips A and B, ſail with equal velocity, they cannot cut or croſs each other, unleſs one be to windward of the other. *Fig.* 50.

2. If the ſhip A, which is to leeward, outſails the ſhip B, ſhe may croſs the other before ſhe gains the wind, and the point where ſhe is to make her tack for that purpoſe, may be determined, if the time ſhe would take up in running through a line equal to the ſpace between them, is nearly known, as thus;

3. Suppoſe the ſhip A is to run the courſe AD, and the ſhip B to run the courſe BE, parallel to AD; and that the time the ſhip A would take to run thro' a ſpace equal to the diſtance AB of the two courſes, were nearly known. Obſerve the time which has paſt ſince the ſhip A anſwer'd to the ſhip B, by the line AB perpendicular to the courſes, and that wherein ſhe anſwers by the line CH, which makes the angle HCA 45 degrees; and from that time, ſubtract the time the ſhip would have taken in running through a line equal to AB, then will the ſquare root of twice the ſquare of the remainder, be the time that the ſhip A ſhould continue on her courſe from the point C, before ſhe makes her tack to croſs the courſe of the ſhip B. Continue AB, and CH, till they meet in the point G; and make CD, and HE, equal to GH; then draw DG, which ſhall cut HE, in the point I; laſtly, compleat the parallelogram GCDF, and draw HL parallel to BA.

I ſay, 1. That the point D, ſhall be the point where the ſhip A ought to tack, according to the rule given.

Demonſt. Since in the rectangled triangle CAG, the angle C is 45 degrees, it will be equal to the angle G, and the lines AC, AG, will be equal; as alſo B H, B G; and C L, L H, or AB. Then ſince from the time that the ſhip has taken to run through the line AC, the time ſhe would have taken to run through the line AB, or CL is taken; the remainder will be the time ſhe has taken in running through the line LA, or HB; and the ſquare root of its ſquare doubled, will be the time ſhe muſt take up in running through GH, or CD: and conſequently the point D, muſt be the point where the ſhip A muſt tack, according to the rule given.

I ſay, ſecondly, That the ſhip A, tacking at the point D, ſhall meet the ſhip B, in the point E.

Demonſt. CD : HI : : CG : HG; or : : CA : HB; then ſince the ſhip A has run through the line AC, while the ſhip B has been running thro' the line BH; ſhe will run through the line CD, while the ſhip B runs through the line HI. Likewiſe ſince DE : EI : : DF : FG, and CG : GH : : CA : BH, the ſhip A ſhall run through the line DE, while the ſhip B runs through IE, and both ſhall come at the ſame time to the point E.

4. It is plain enough, that in practice the ſhip A ſhould run ſomething beyond the point D, by reaſon ſhe will loſe ſome time in tacking.

PROP. XXV.

Remarks upon giving Chace.

1. If the diſtance AB between the courſes of the two ſhips is ſmall, it *Fig.* 50.

will be beſt for the ſhip A to hold on her courſe, till in tacking ſhe can cut the other.

2. If the diſtance AB is very great, the ſhip A ought not to ſtand ſo far on one tack, as in changing her board to expect to cut the ſhip B, leſt ſhe ſhould run too far, and ſo the ſhip B eſcape, either by being favoured by the wind, or imperceivably making ſome alteration in her courſe.

3. Neither ought a ſhip to tack, every time ſhe ſhall ſee the ſhip ſhe chaſes about; by reaſon of the time ſhe will thereby loſe.

4. I think it may be laid down for a general rule, *always to tack upon the veſſel in chace:* that is to ſay, that the ſhip A ought not to tack, till the ſhip B is fix'd in her courſe after tacking, by which means ſhe will never be diſtanc'd from the ſhip in chace; and if the wind does not ſhift, will probably fetch her up on the ſecond tack; or if the wind does ſhift, if to her advantage, ſhe will be ready to reap the benefit of it; or if on the contrary, ſhe will be the readier to recover the diſadvantage.

5. In regard to the ſhip that is chaced, ſhe ought, 1. To make the beſt of the inadvertencies of her adverſary; ſhe ſhould often change her courſe, and keep to that ſhe finds moſt to her advantage; that is to ſay, that which diſtances her moſt from her enemy: 2. Not to be too ſolicitous to keep cloſe upon the wind, if ſhe ſails better with a large wind; for as the wind often changes during a chace, ſhe may poſſibly find herſelf to leeward, by keeping the wind too cloſe.

3. Above all things avoid keeping up to the wind, when you are very much to leeward of your enemy; on the contrary, go a little more large away than he, unleſs he ſteers directly down upon you, for in that caſe you muſt ply to windward.

Prop. XXVI.

Of boarding a Ship.

1. If the veſſel you would lay aboard be at anchor, you may anchor on his buoy, and veer away your cable till you fall aboard him; but then too he may cut away, and ſo you may loſe your labour.

2. Neither would I adviſe the furling your ſails in falling aboard him; becauſe it will be eaſy for him to keep you off with his boombs and boats.

3. This way then I would prefer. Firſt, I would get my ſprit-ſail yard fore and aft, then with may top ſails a trip, I would lay him aboard on the bow. In this manner I ſhould have more time and means to grapple him faſt.

4. If the ſhip you would board is under ſail, and keeps her wind, it would be beſt then too, to board her on the bow, but it muſt be to windward elſe ſhe may eaſily avoid you, by keeping her wind cloſe: If in the inſtant you lay her aboard, ſhe wares from you, you muſt ware after her, or ſhe will ſhoot a-head of you, which if you cannot avoid, be ſure you keep the weather-gage of her, for the next opportunity of boarding.

5. If the ſhip you would board, goes before the wind, and you can out-ſail her, range up along her ſide, before you ſheer aboard her.

6. When your Ship is under ſail, you may eaſily avoid being boarded. For 1. If the enemy would board you on your bow to windward, you may ware ſhort round; and if the enemy wares too, you may take luff for luff, which will infallibly put her to leeward of you; if the enemy keeps the wind, wait till ſhe has paſt you a ſtern, and then tack again to the wind upon the ſame board you were before, which will entirely prevent his boarding you. 2. If he would board you on your bow to leeward, keep as cloſe as poſſible to the wind, ſo ſhall the wind of your ſhip ſupport you, and becalm him, which will conſequently make him fall to leeward, and a-ſtern. 3. If your enemy would board you on the poop, it will be eaſy to avoid it, by giving your ſhip ever ſo ſmall a ſheer the contrary way.

7. If two ſhips, friends, come with a large wind one againſt the other, they may avoid running foul, if the one falls off ever ſo little, while the other keeps her wind; but if one is cloſe upon a wind, the other ought to fall off, becauſe a ſhip cloſe haled is not always ſo ready to ware.

8. If a ſhip is coming athwart you a-head, you may avoid it, by laying all your ſails a-back, if you are to leeward, but if you are to windward, ſhe ought to ware ſhort.

Fig. 51. 9. If in ſailing on a wind in a line of battle, the ſhip A a-head be taken at ſtays, ſhe will be in danger of falling aboard the ſhip B which follows; in this caſe the ſhip B muſt not put to ſtays for fear of falling on a third, and unleſs ſhe wares a great deal, ſo as to run out of her line, ſhe will only bear up into the others way, by the line BD; ſhe ſhould therefore luff up, even to touching into the wind, from whence theſe two things will follow, 1. The ſhip B will leſſen her way. 2. She will get out of the line in which the ſhip A falls, by keeping the line BF.

10. If the ſhip A being at anchor, is like to be run aboard by the ſhip B, *Fig.* 52. the ſhip B ought to ware ſhort round; but if they are obſtinate and will not, the ſhip A ought immediately to veer away her cable. If the ſhip coming on the ſhip A, be cloſe on her wind as C, ſhe ought ſpeedily to lay all aback, unleſs ſhe is ſo much to windward as D, for then ſhe ought to keep as much of her wind as poſſible, ſo as not to ſhake all her ſails, leſt in laying aback ſhe drive foul of the ſhip A.

11. If in a calm the current throws the ſhip B upon the ſhip A at anchor, *Fig.* 53. the ſhip B muſt be tow'd a ſtern with boats; unleſs ſhe be ſo far advanc'd athwart her, that it would be eaſier to tow her clear a-head.

12. If the ſhip A at anchor, drives upon the ſhip B likewiſe at anchor, *Fig.* 54. they muſt both veer out cable, for it is the only means to bring him up that drives; it will be alſo proper for him to carry out another anchor.

13. If

Fig. 55. 13. If the ſhip A drives, and the current CD throws her upon the ſhip B at anchor, where the channel is of a ſufficient breadth, the ſhip A muſt veer out cable, and back her mizzen-top-ſail, to make her fall towards E, till her anchor takes, or ſhe falls beyound the ſhip B. In this caſe, as the cables will probably croſs each other, one muſt cut or veer it quite out, with a buoy at the end.

14. There may be many other circumſtances with relation to the boarding of ſhips, which might perhaps require particular rules; however, theſe laid down will ſufficiently lead to whatever elſe may occur in practice.

PROP. XXVII.

Of running into Land.

1. If you are obliged to run in upon an unknown coaſt, make as little ſail as poſſible, ſending out your boats to ſound a-head, and at the ſame time keep the lead going on both ſides aboard; when you think you have a good birth for anchoring, brace too to give time for the boats to ſound all about; you may then, if you find the place convenient, anchor, but not moore, till you have better examined it, ſounding all around, and ſetting the neighbouring capes, to know if you have ſafe riding. Laſtly, if you have time, make your ſef perfectly acquainted with the place, and lay down a plan thereof.

2. If you are acquainted with the land you are running into, ſet the head-lands you know, to find

the exact point where you are, then running in with ſmall ſail, obſerve the proper marks which lead you to good anchorage.

Prop. XXVIII.

To bring a Ship to an Anchor.

1. In fine weather, drawing near your anchoring-place, get your anchor clear, and your buoy ready to ſtream, alſo take a range with the cable about the bits, in proportion to the depth of water you are to anchor in; at the ſame time furl your main-ſail, hale up your fore-ſail, and lower a little your top-ſail yards. Laſtly, when you are come to your anchoring-place, hale out the mizzen to bring up the ſhip to the wind, then clewing up one of the top-ſails, brace too the other to ſtop her way, which when ſhe has wholly loſt, and begins to fall, let go your anchor, and veer away your cable till your anchor is a-ground, which if you have any wind, and the ſhip will fall, keep ſtill veering, till you have as much out as you think proper; if the ſhip will not eaſily fall a-ſtern, you may help her with the mizzen-top ſail aback.

2. If there be any currents againſt the courſe, you muſt not hale up all your ſails till at the place of anchorage, otherwiſe the currents will ſoon carry the ſhip away again.

3. You may alſo in fair weather, come to an anchor with all your ſails abroad; laying all aback to ſtop the ſhip's way the moment before you come to. But this is not ſo convenient, unleſs you have a great many hands to furl at once.

4. In bad weather, it is moſt proper to come to with the fore-ſail only; by bracing which aback, you may ſtop the ſhip's way. 2. In ſuch caſe, take two turns with your cable about the bits. 3. Let go the weather anchor, leſt the veſſel in falling ſhould rub the cable againſt her cut-water. 4. Veer away a great ſcope of cable to ride her.

PROP. XXIX.

To Moor.

1. In places where the tides are commonly ſtronger than the winds, you moor according to the ſet of the tides; that is to ſay, if the tides ſet eaſt and weſt, your anchors ought to lie eaſt and weſt.

2. Ships generally moor with a large anchor and a leſs, commonly the ſmall bower; giving the greater ſcope of cable to the beſt anchor; which is always laid where the moſt danger is expected.

3. In places where the tides are very ſmall, and the winds generally ſtrong, you ſhould moor in a line perpendicular to the wind, that ſo both your cables may bear alike; which cannot be done in a tide, where there are two motions entirely oppoſite.

4. Moſt commonly the anchor you moor with is carried out with the boat, and ſo dropp'd as to anſwer right with the larger anchor a-head; but if it be neceſſary, by reaſon of bad weather, to moor with too large anchors, after having let go your firſt, carry out a ſmall anchor in your boat, ſomething farther than you deſign to let drop the

ſecond, and heave your ſhip by the ſaid ſmall anchor, till you come to the proper place to let go the ſecond. In this caſe there ſhould be but a ſmall range of cable allowed to the ſecond anchor, leſt falling all at one to the ground, it ſhould break or bend; but bitting it ſhort, pay out the cable gently, as you recover that of the firſt anchor.

5. In fair weather, coming to an anchor, you may moor in this manner: Hale up your courſes, and take in the main-top-ſail, then letting go your anchor without bitting it, and with a good range, pay out the cable very faſt, and ſhoot your ſhip over with the fore-top-ſail, till you are where you would let go the other anchor, which do with the former precautions; after which as before, heave in the cable of the firſt anchor, as you veer out this.

6. Where you have ſtrong tides, 'tis very eaſy to moor, by veering away your cable upon the ſtrength of the tide, till it is proper to let go the other anchor; then in heaving in the firſt cable, you veer away the ſecond.

REMARKS.

1. The reaſons of ſeveral of the rules above given are omitted, becauſe they are ſelf-evident.

2. Many things too I have let paſs, that I might not run this Tract into too great a length; beſides, that for the moſt part, thoſe things which are omitted, are ſuch as will be eaſily learn'd in practice, tho' very difficult to be explain'd.

3. Thoſe operations which depend more immediately on Mechanicks, may ſerve as corollaries to the Tract upon that ſubject.

Before we proceed to the Explanation of Terms uſed in this Work, I muſt deſire the Reader to obſerve what was ſaid in prop. 4. that the head-ſails hinder a ſhip from yawing, is not to be underſtood, as if you were to increaſe the head-ſails, that ſhe might yaw leſs; it being certain, a ſhip fetches the greater ſheers, the greater way ſhe has thro' the water. It is therefore only meant, that the head-ſails correct the yaws a ſhip will neceſſarily take in a ſea; ſo that if a ſhip were thruſt forward in a certain velocity by her after-ſails, ſhe would ſheer more, than if thruſt on with the ſame velocity by her head ſails only. So alſo in 4. of the ſame propoſition, when it is ſaid the head-ſails bring a ſhip to, it is to be underſtood as there explained, for the head-ſails being aback, flat her off from the wind.

AN ALPHABETICAL EXPLANATION OF SUCH NAVAL TERMS AS

Occur in the foregoing TRACTS; or are occaſionally uſed in this, for the Explanation of others.

A

AFT, or ABAFT; is a ſea-term to diſtinguiſh between things done, or plac'd from-wards the ſtem or fore-part of a ſhip, towards the ſtern, or hind-part: As when they ſay, come *aft* or go *aft*; that is, go towards the ſtern. Haul the ſheet *aft*: The maſt hangs *aft*; that is, towards the ſtern.

Aftward, the hinder part of the ſhip.

ALTITUDE of the ſun, or a ſtar. Height above the horizon.

ANCHOR, is a maſſive iron, which being caſt into the ſea or river, by ſticking faſt in the ground, prevents a ſhip's being carried away with the wind or current. It conſiſts of a ſhank or beam, with flooks at one end to enter the ground, and a ſtock of wood at the other, ſerving to guide the flooks; it has alſo a ring, by which it is faſtened to the cable.

There are ſeveral ſorts of *anchors*, differing only in weight, which is according to the burden of the ſhip.

Sheet-anchor, is the greateſt of all that belong to a ſhip, and is never uſed but in great neceſſity, as being their utmoſt refuge, when forc'd to ride on a lee-ſhore.

Bow anchor, *firſt* and *ſecond bower*, or *beſt* and *ſmall bower*, are ſuch as the ſhip in fair weather may ride by.

Kedge-anchor, or *kedger*, uſed in calm weather, in a low ſtream, or to kedge up and down a narrow river, leſt the wind or tide ſhould drive the ſhip aſhore. See KEDGING.

Grapples, or *Graplings*; are the ſmalleſt of all the *anchors*; they have four flooks, but no ſtock. Their uſe is for a boat to ride by; or to throw into an enemy's ſhip in a cloſe engagement, to catch hold of the gratings, rails, &c. in order for boarding her.

To ride at anchor, is ſaid of a ſhip which is held faſt by her *anchors*, ſo as not to be driven with either wind or tide.

To caſt or *drop anchor*, is to let it fall, to ſtop the courſe of the ſhip.

To weigh anchor, is to get it up, in order to ſet ſail.

To ſhoe an anchor, is to put boards fitted for that purpoſe, on the flook, that the anchor may the better hold in ſoft ground.

The anchor is foul; that is, the cable is hitch'd about the flook, by the turning about of the ſhip.

The anchor is come home, is ſaid when it does not hold the ſhip, but that ſhe drives away by the violence of the wind or tide.

The anchor is a-peek; that is, the *anchor* is right under the hawſe (or hole) through which the cable belonging to that anchor runs out.

The anchor is a cock-bell; that is, hangs right up and down by the ſide of the ſhip, ready to be dropt.

Pudding of the anchor, are thoſe ropes which are wound round the ring, to ſave the clinch of the cable from being gaul'd by the iron.

B

BEAK, or *Beak-head*; is that ornamental projection at the head of a ſhip, ſupported by the cut-water.

BEAM. The *beams* are thoſe great croſs timbers, which keep the ſhip's ſides aſunder, and ſupport the decks. The *main-beam*, or *midſhip-beam*, or, as it is called by way of eminence, The *Beam*, is that next the main-maſt, and is the meaſure of the ſhip's breadth.

BEAR; is a word us'd at ſea in various ſenſes, as in the following inſtances:

Bear up; that is, let the ſhip ſail more before the wind.

Bear up round; that is, put her right before the wind.

Bears in with the land or harbour; that is, the ſhip ſails towards the ſhoar or harbour, with the wind large, or before it.

Bears off; that is, keeps from the land.

The ſhip bears a good ſail; that is, having all her ſails abroad in a gale of wind, ſails upright in the water.

To bring the guns to bear; that is, to lie right with the mark.

BEARING; the point of the compaſs that one place bears from another.

To BELAY, is to make faſt a rope in its proper place.

BIRTH, is a convenient place to moore a ſhip in; as alſo a due diſtance obſerved between ſhips lying at anchor, or under ſail.

BITTS, are two main pieces of timber ſtanding pillar-wiſe abaft the manger, in the loof of the ſhip, with a croſs-piece for belaying the cable when the ſhip rides at anchor. In great ſtorms, to ſtrengthen the *bitts*, and ſecure the bows, the cable is faſtened to the main-maſt.

BOARD, is a word variouſly uſed at ſea; as,

To go aboard; ſignifies to go into the ſhip.

To heave over board; is to throw a thing out of the ſhip into the ſea.

To ſlip by the board; is to ſlipt down by the ſhip's ſide.

Board and board; is when two ſhips come ſo near as to touch one another; or when they lie ſide by ſide.

To make a board; is to turn to windward; and the longer your *boards* are, the more you work into the wind.

To board it up, is to beat it up ſometimes upon one tack, and ſometimes upon another.

She makes a good board; that is, the ſhip advances much at one tack.

The weather board, is that ſide of the ſhip which is to windward.

To board a ſhip, is to enter an enemy's ſhip in a fight.

BOOM, is a long piece of timber with which the clew of the ſtudding ſail is ſpread out; and ſometimes the clew of the main-ſail and fore-ſail is *boom'd* out, that by ſpreading them the broader they may receive the more wind.

Booming; we ſay a ſhip comes *booming* towards us, when ſhe comes with all the ſail ſhe can make.

BOW *of a ſhip*, is that part of her, which begins at the loof and compaſſing ends of the ſtem, and ends at the ſtern-moſt part of the fore-caſtle.

Bow-line, is a rope made faſt to the leech or middle part of the out-ſide of the ſail; it is faſtened by two, three or four ropes like a crow's foot, to as many parts of the ſail; only the mizzen bow-line is faſtened to the lower end of the yard; this rope belongs to all ſails except the ſprit-ſail, and ſprit top-ſail; therefore thoſe ſails cannot be uſed cloſe by a wind, for want of room to hale the bow-line forward by, ſince the uſe of the bow-line is to make the ſails ſtand ſharp, or cloſe by a wind.

BRACES, are ropes belonging to all the yards of a ſhip, except the mizzen, two to each yard, reev'd through blocks that are faſtened to pennants ſeiz'd to the yard arms: Their uſe is either to ſquare, or to traverſe the yards. All theſe braces come aft-ward on, as the main-braces come to the poop; the main top-ſail braces to the mizzen-top, and thence to the main ſhrouds; the fore and fore top-ſail *braces* come down by the main and main-top-ſail ſtays; and ſo of the reſt. But the mizzen bow-line ſerves to *brace* to that yard; and the croſs-jack *braces* are brought forward to the main ſhrouds, when a ſhip ſails cloſe by a wind.

BUOY, is a ſhort piece of wood, or cloſe-hoop'd barrel, faſtened ſo as to float directly over the anchor; and by that means it is always known whereabout it lies.

Stream the buoy; that is, let the anchor fall while the ſhip has way.

To buoy up a cable, is to faſten ſome pieces of wood, barrels, *&c.* to the cable near the anchor, that the cable may not touch the ground, in caſe it be foul or rocky, leſt it ſhould be fretted, and cut off.

C

CABLE, is a great rope faſtened to the anchor, and proportioned to it; ſerving to keep the ſhip faſt while ſhe rides at anchor.

Serve or plat the Cable; that is, bind it about with ropes, clouts, *&c.* to keep it from gawling in the hawſe.

To ſplice a cable, is to make two pieces faſt together, by working the ſeveral ſtrands of the rope one into another.

Pay more cable, that is, let it more out from the ſhip, that the boat which carries the anchor may row the eaſier, the *cable* lying ſlack in the water.

Pay cheap the cable, that is, put or hand it out apace.

Veer more cable, that is, let more of it run out.

A ſhot of cable; when the *cable* is double in length, to make the ſhip ride the eaſier.

To quoil a cable, is to roll it up in a ring.

To bend, or unbend a cable, is to faſten it to, or looſe it from the ring of the anchor.

CAPSTAN. Ships have uſually two (tho' both of the ſame form) diſtinguiſh'd by the names of the *main-capſtan* and the *jeer-capſtan*; the *main-capſtan* is a great piece of timber in the nature of a windlaſs, but ſtanding perpendicularly juſt abaft the main-maſt, its foot ſtanding in a ſtep on the lower deck, and its head between the two upper decks, form'd into ſeveral ſquares with holes in them. Its uſe is to weigh the anchors; to hoiſt up, or ſtrike down the top maſt; to heave any weighty thing; or to ſtrain any rope that requireth a main force. The *jeer-capſtan* is plac'd between the main-maſt and the fore-maſt, and ſerves to ſtrain any rope, to heave upon the jeer-rope, or upon the viol, or hold off by, at the weighing of an anchor.

Capſtan-bars, are the bars or pieces of wood that are put into the *capſtan* holes to work the machine in heaving up any thing of weight into the ſhip, by the help of as many men as can well ſtand at them.

Spindle of the capſtan, is the main body thereof.

Whelps of the capſtan, are ſhort pieces of wood like brackets, made faſt to it to keep the cable from coming too nigh in turning it about.

Pawl of the capſtan, is a ſhort piece of iron made faſt to the deck, cloſe to the body of the *capſtan*; but yet ſo as that it hath liberty to turn every way, and againſt it the whelps of the *capſtan* do ſo bear, that the *capſtan* may be thereby ſtopt from turning or reverſing, and this ſtoppage is term'd *pawling the capſtan.*

Man the capſtan; that is, have all the hands neceſſary to heave at the *capſtan* bars.

Come up capſtan, or *launch out the capſtan*; that is, ſlack the cable which you heave by.

CHASE, ſignifies the ſhip chaſed or purſued.

CHASER, is the ſhip in purſuit of the chaſe.

Stern chaſe, is when the chaſe is right a-head of the chaſer.

To lie with a ſhip's fore-foot in a chaſe, is to ſail the neareſt way to meet her, and ſo to croſs her in her way, or *to come acroſs her fore-foot.*

CHESSE-TREES, are two ſmall pieces of timber with a hole in them, on each ſide of the ſhip, a little before her loof; their uſe is for the main-tack to run through, and to hale it down to.

CLEATS; or, as ſome call them, *Chevils*, *Kevels*, or *Knevels*, are ſmall pieces of wood nailed to the inſide of the ſhip: Their uſe is to belay the ſheets and tacks unto. *Cleats* are alſo pieces faſtned on the yard arms, to keep the ropes from ſlipping off the yard.

CLOSE-HAWL'D; a ſhip is ſaid to be *cloſe-hawl'd*, when her ſails are trim'd ſharp, ſo as to ſail as near the wind as poſſible.

CLEW *of a ſail*, is the lower corner of it, to which are made faſt the ſheets and tacks.

COUNTER *of a ſhip*, is uſually diſtinguiſhed into upper and lower.

Upper-counter, is the hollow arching from the gallery to the lower part of the ſtrait-piece of the ſtem.

Lower-counter, is between the tranſom, and the lower part of the gallery.

COURSE *of a ſhip*, is that point of the compaſs on which ſhe ſails; and is indeed the angle, that the rumb line ſteer'd upon makes with the meridian.

COURSES, are the lower ſails, particularly the main-ſail and fore-ſail.

CUT-WATER, is that thin projecting knee under the beak-head, and is ſo call'd, becauſe it cuts or divides the water before it comes to the bow.

D

DECK *of a ſhip* is a plank'd floor from ſtem to ſtern, whereon is plac'd the ordnance, and on which the men walk. Great ſhips have three *decks*, firſt, ſecond, and third, beginning to account from the lowermoſt.

Half-deck, reaches from the main-maſt to the ſtem of the ſhip.

Quarter-deck, is that aloft the ſteerage, reaching to the round-houſe.

F.

FALL *of a tackle*, is that part of the rope which is haled upon.

Fall off; a ſhip is ſaid to fall off, when in ſailing ſhe keeps not ſo near the wind as ſhe ſhould do.

FATHOM; a meaſure of ſix foot.

FORE *and aft*; that is, from ſtem to ſtern.

FRESHENS; the wind *freſhens*, that is, blows ſtronger.

FURLE, (bind or make up) as to *furle* a ſail, is to wrap up, and bind it cloſe to the yard.

G

GAGE, a ſhip's *gage*, is ſo many feet as ſhe ſinks in the water, or ſo many feet of water as ſhe draws; which ſeamen find thus: They drive a nail into a pike near the end, then putting it down by the rudder till the nail catch hold under it; for then as many feet as the pike is under water is the ſhip's *gage*.

Weather gage; when one ſhip has the wind, or is to windward of another ſhe is ſaid to have the *weather-gage* of her.

To GRAPPLE, is to hook faſt an enemy's ſhip, in order for boarding.

GRAPPLING. See ANCHOR.

GRIPE; the *gripe* of a ſhip, is the compaſs and ſharpneſs of the ſtern under water, eſpecially toward the lower part. The uſe thereof is to make a ſhip keep a good wind, and therefore ſometimes when a ſhip will not keep a wind well, they put on another falſe ſtem to the true ſtem, to make her *gripe* more.

To gripe; we ſay a ſhip doth *gripe*, when ſhe is apt (contrary to the direction of the helm) to run her head more in the wind than ſhe ſhould. There may be two cauſes of this, the one when a ſhip is too deep a-head, ſo that by reaſon of the weight which preſſes down her head, ſhe is unapt to fall away from the wind; the other may be the ſtaying of the maſts; for if ſhe be a ſhort ſhip, and draw much water, if her maſts be ſtay'd too much aft, it will cauſe her head ſtill to run into the wind.

H

HALE, ſignifies pull, as to *hale up*, is to pull up; to *hale in* or *out*, is to pull in or out.

HAWSES, are great holes in the ſhip's head through which the cables run, when ſhe lies at anchor.

Bold hawſe; that is, when the holes are high above the water.

Freſh the hawſe, or *veer out more cable*; is when part of the cable that lies in the *hawſe* is fretted or chafed, and it is requiſite that more cable ſhould be veered out, ſo that another part of it may reſt in the *hawſe*.

Freſh the hawſe; that is, lay new pieces upon the cable in the *hawſe*, to preſerve it from fretting.

Burning in the hawſe; that is, when the cable endures a violent ſtreſs.

Clearing the hawſe; when two cables that come through ſeveral *hawſes* are twiſted and entangled one with the other; the untwiſting of them is call'd *clearing the hawſe.*

Thwart the hawſe, or *rides upon the hawſe*; that is, when a ſhip lies thwart, or croſs, or with her ſtern juſt before another ſhip's *hawſe.*

HAWSER, is a great rope, or a ſort of ſmall cable, ſerving for various uſes aboard a ſhip; particularly to warp a ſhip by as ſhe lies at anchor, and wind her up to it by a capſtan, &c. Note, *hawſers*, like cables, are in proportion to the ſhips for whoſe uſe they are deſign'd; for a great ſhip's *hawſer* may ſerve for a cable to the ſheet anchor of a ſmall ſhip.

HEAD *ſails*, are the ſails belonging to the fore-maſt and bolt-ſprit; for they govern the head of the ſhip, and do make it fall of; and theſe in quarter-winds are the chief drawing ſails.

HEAVE; that is, to throw away; as *heave it over board*; that is, fling it over board.

Heaving at the capſtan; that is, turning about the capſtan.

Heave and ſet; that is, when a ſhip being at anchor, riſes and falls by the force of the waves, ſhe is then ſaid to *heave and ſet.*

HELM, or *Tiller*, is that piece of timber which is faſtned into the rudder, and ſo comes forward into the ſteerage, or place where he at the helm ſteers the ſhip, by holding the whip-ſtaff in his hand. Large ſhips have commonly a wheel like thoſe in cranes, plac'd between the quarter-deck and coach, which has ſeveral advantages above the common method.

Bear up the helm; that is, let the ſhip go more large before the wind.

Helm a mid-ſhip, or *right the helm*; that is, keep it even with the middle of the ſhip.

Bear up round; that is, let the ſhip go directly before the wind, in the middle, between her two ſheets.

Port the helm; that is, put the helm over to the left ſide of the ſhip.

Starboard the helm; that is, put it to the right ſide of the ſhip.

Eaſe the helm; that is, let the ſhip go more large, or more before the wind.

Feel the helm; a ſhip is ſaid to feel her helm when ſhe ſteers readily.

HOISE, is to hale up any thing into the ſhip; or getting up a yard, *&c.* as *hoiſe* up the yard; *hoiſe* the water in, *&c.*

HULL *of a ſhip*, is the full bulk, or main body of a ſhip, from ſtem to ſtern, without either maſts, or rigging.

To ſtrike a hull; thar is, in a ſtorm, to lie cloſe in the ſea, or tarry for ſome conſort, bearing no ſail, with the helm laſhed a-lee.

To hull, or *lie a hull*, or *hulling*; is ſaid of a ſhip when either in a dead calm, (to prevent her beating the ſails againſt the maſts by rolling) or in a ſtorm, when ſhe cannot carry them, ſhe takes all her ſails in; ſo that nothing but her maſts, yards, and rigging are abroad; the helm is laſh'd faſt to the ee-ſide of the ſhip: In this condition, if ſhe is a good ſailer, ſhe will lie eaſily under the ſea, and make her way one point before the beam.

K

KEDGING, is when a ſhip is brought up or down in a narrow river, the wind being contrary to the tide, and yet ſhe is to go with the tide: They ſet the fore-ſail, fore top-ſail, and mizzen-ſail, and let the ſhip drive with the tide, ſo that they may flat her about: And if ſhe happen to come too near the ſhoar, then having a ſmall anchor in the head of the boat, with a ſmall hawſer faſtned to it from the ſhip, they let it drop in the middle of the ſtream; and this will *wend*, or turn her head about; when ſhe is come fully about, they heave up the anchor again. This ſort of working is called to *kedge*, or *kedging*; and the anchor thus uſed is called a *kedger*.

KEEL, is the firſt or loweſt piece of timber in a ſhip; it lies in the very bottom of her hull, one end whereof is at the ſtern, the other at the ſtem; and into this, are all the ground timbers and hooks faſten'd and bolted fore and aft.

Falſe keel, is a keel put on under the firſt, in caſe the ſhip be ſhallow, and ſo over-floaty, and roll too much.

L

LARBOARD, is the left-hand-ſide of the ſhip, when you ſtand with your face towards the head.

LARGE; *a ſhip goes large*, that is, ſhe goes neither before the wind nor upon the wind; but, as it were, *quartering* between both, with a freſh gale, and all ſails drawing.

To ſail with a large wind, that is, with a fair wind.

LEE. This word is variouſly uſed; but generally ſignifies the part oppoſite to the wind; as the *lee-ſhoar* is the ſhoar againſt which the wind blows; but to be under the *lee* of the ſhoar, is to be cloſe under the weather ſhoar, that is, the ſhoar whence the wind doth come.

Lee-hatch: Have a care of the lee-hatch; that is, take care the ſhip does not go to the leeward of her courſe.

A lee the helm; that is, put the helm to the leeward ſide of the ſhip.

To lie by the lee; or *to come up by the lee*; is to bring the ſhip ſo, that all her ſails may lie flat againſt her maſts and ſhrouds, and that the wind may come right upon her broad ſide.

LOG, is a little piece of wood of a triangular form, with as much lead in one end thereof, as will ſerve to make it ſwim upright in the water, at the other end it is made faſt to the *log-line*.

Log-line, is a ſmall line, having the *log* faſtned to one end; and is wound upon a reel. The *log-line* for about 10 fathom in ſmall ſhips, or more in great ones from the *log*, has or ought to have no knots or diviſions, becauſe ſo much ſhould be allowed, that the *log* may be out of the eddy of the ſhip's wake, before the glaſs be turn'd up: Then the knots begin, and ought to be at leaſt 50 feet aſunder; though the common practice at ſea is to have them but 7 fathoms, or 42 feet diſtance. The uſe of the *log* and *log-line*, is to make an eſtimate of the ſhip's way, or diſtance run, by heaving it every hour, or every two hours.

To heave the log, is firſt to to throw it into the water, and let it run away ſo far, as to be out of the eddy of the ſhip's wake; then one having a half-minute glaſs ready in his hand, turns it up juſt when the firſt knot runs off the reel; and ſo the line running eaſily off as the ſhip moves, when the glaſs is out, he cries *ſtop*, and the other ſtops the reel: Then counting the knots run out with the odd fathoms or feet (if any) they reckon, for as many knots as run out in half a minute of time, ſo many miles the ſhip ſails in an hour; and for every 5 odd feet, a tenth part of a mile more. Thus three knots in half a minute, is three miles an hour; and four knots 25 feet in half a minute, is four miles and a half an hour.

The common diviſion of the *log-line*, is grounded upon this ſuppoſition; that a mile contains 5000 feet, and 60 of ſuch miles a degree; whence a degree would contain 300000 feet. Now half a minute being the 120th part of an hour, and the 120th part of 5000 feet being 41,6, &c. or near 42 feet, therefore as many times 42 feet as the ſhip runs in half a minute, ſo many miles ſhe goes in an hour. So that according to this ſuppoſition, 42 feet muſt be the diſtance between the knots upon the *log-line*. But this ſuppoſition, and conſequently the practice from it, is certainly erroneous; for a degree is now found to contain 360000 feet at leaſt; therefore a minute or a mile muſt contain 6000 feet (which is the true ſea mile) and ſince half a minute is the 120th part of an hour, the 120th part of 6000 feet is 50 feet, conſequently as many times 50 feet as the ſhip runs in half a minute, ſo many miles ſhe makes in an hour (ſuppoſing her to hold her pace) therefore the diſtance between knot and knot ſhould be 50 feet.

LOOF, or *Louf* of a ſhip, is that part of her aloft, which lies juſt before the cheſſe-trees.

Loof or *Luff*, is alſo a word uſed in conding a ſhip: As,

Luff, *keep your Luff*, that is, keep the ſhip near the wind.

Luff up, that is, keep nearer the wind.

To luff into a harbour; is to ſail into it cloſe by the wind.

To ſpring the luff, is when a ſhip that before was going large before the wind, is brought cloſe by the wind.

Loxodromick-line, is the line of the ſhip's way when ſhe ſails upon a rhumb oblique to the meridian.

LYE *under the ſea*; is ſaid of a ſhip when her helm is laſh'd faſt a-lee, and ſhe lies ſo a-hull, that the ſea breaks upon her bow, or broad ſide.

M

MOOR; to *moor* a ſhip, is to lay out her anchors ſo as is moſt convenient for her ſafe and ſecure riding. A ſhip is not ſaid to be *moor'd*, unleſs ſhe has at leaſt two anchors out.

P

POINT *of the compaſs*, is the 32d part of the circumference of the circle on the card, or 11 degrees 15 minutes; therefore *half a point* is 5 degrees 37 minutes; a *quarter point* is 2 degrees 48 minutes.

POOP *of a ſhip*, is the higheſt, or uppermoſt part of her hull a-ſtern.

PORT, or *port the helm*, is a word of command to him at the helm, to put it to larboard, which will make the ſhip go to ſtarboard.

The ſhip heels a-port, that is, leans to the left.

Ports, are thoſe holes in a ſhips ſide, through which the great guns are put out.

Q

QUARTER *of a ſhip*, is that part of the ſhip's hull which lies from the ſteerage-room to the tranſom.

QUARTERING; *the ſhip goes quartering*, that is, ſhe goes upon a quarter-wind; or ſhe goes neither by a wind, nor before the wind, but betwixt both.

Quarter-wind, is when the wind comes in abaſt the main-maſt ſhrowds, even with the quarter.

R

RAKE *of a ſhip*, is ſo much of her hull as hangs over both ends of her keel.

Fore-rake, or *rake-forward*, is that part of it which is before, and is uſually more than a third, but leſs than half the length of the keel. A long *rake* forward gives the ſhip a good way; but then if ſhe has not a full bow, it will make her apt to pitch much a head into the ſea; beſides, is a great charge and ſtreſs to a ſhip; becauſe ſhe hangs over ſo a-head. But when a ſhip has a ſmall *rake* forward, ſhe becomes ſo bluff-headed, that the ſea beating continually upon her bow, ſhe cannot cut the water ſo readily as ſhe ought, and conſequently will make but ſmall way.

Rake-aft, or *rake-aftward*, is that part which is at the ſetting on of the ſtern-poſt, and is generally about a fourth or a fifth part of her *fore-rake.*

Rake of the rudder, is the aſt-moſt part of the rudder.

REEVE, is to draw a rope through a block to run up and down.

RIDE; a ſhip is ſaid to *ride*, when her anchors hold her faſt, ſo that ſhe drives not by the force of the wind or tide. And a ſhip is ſaid to

Ride well, when ſhe is built ſo, that ſhe does not over-beat her-ſelf into a head-ſea, ſo that the waves do not ovor-rake her, that is, over-waſh her from ſtem to ſtern.

Ride a-thwart, is to ride with her ſide to the tide; and then ſhe never ſtrains her cable.

Ride betwixt wind and tide, is to ride ſo that the wind has equal force over her one way, and the tide the other; which makes a ſhip roll and tumble very much, yet not ſtrain her cables much.

Ride hawsful, or *to ride a ſtreſs*; that is, when in a ſtreſs of weather, the ſhip falls deep into the ſea with her head, ſo that the water runs in at her hawſes.

ROAD, is any place near the land, where ſhips may ride at anchor.

RUDDER *of a ſhip*, is a piece of timber which hangs at the ſtern-poſt, having four, five, or ſix irons, called *pintles*, according to the bigneſs of the ſhip, which pintles are fitted to the gudgins at the ſtern-poſt; this *rudder* is, as it were, the bridle which governs the ſhip; the narrower the *rudder* the better, if the ſhip do feel it, for a broad *rudder*, as it holds much water, too much ſtops a ſhip's way, when put over to either ſide;

but if the ſhip have a fat quarter, ſo that the water cannot come quick and ſtrong to the rudder, then ſhe will require a broad rudder. The putting to of the rudder, is term'd *the hanging of the rudder*. The part or edge next the ſtern-poſt, is call'd *the inſide of the rudder*; the aftermoſt part, is call'd *the rake of the rudder*.

The rudder rope, is a rope reev'd thro' a hole in the rudder near the head, and likewiſe through the ſtern poſt, both ends being ſplic'd together. Its uſe is, to ſave the rudder, if by any accident it chance to be unhung.

RUMB, *Rhumb*, or courſe of a ſhip, is the angle which ſhe makes in her ſailing with the meridian of the place where ſhe is. See COURSE.

Complement of the rumb, is the angle made by the line of the ſhip's way, with any parallel to the equator.

Rumb ſignifies alſo one point of the mariners compaſs, or the 32d part of the card, or horizon, that is, 11 degrees 15 minutes.

Rumb-line, is the line that is deſcrib'd by the ſhip's motion, on the ſurface of the ſea, ſteer'd by the compaſs, making equal angles with every meridian. Theſe *rumb lines* are heliſpherical, or ſpiral lines, proceeding from the point ſet out from, winding about the globe of the earth, and after infinite revolutions come to the pole, where they end. See LOXODROMICK-LINE.

In plain and *Mercator*'s ſailing, theſe rumb lines are repreſented by ſtrait lines. Their uſe is, to ſhew the bearing of any two places one from another; that is, upon what point of the compaſs any place lies from another.

RUN *of a ſhip*, is that part of her hull under water, which comes narrower by degrees from the floor-timbers to the ſtern-poſt. This is alſo call'd *the ſhip's way aft-ward*; and according to the ſhip's *run*, ſhe ſteers well or ill, by reaſon of the eaſineſs or difficulty of the water's paſſage to the rudder. If too ſhort, and too full below, the water comes but ſlowly to the rudder, becauſe the force of it is broke by her breadth. This is ſometimes remedied by putting on a falſe ſtern-poſt, tho' it is better to lengthen her.

Good run; a ſhip is ſaid to have a *good run*, when ſhe comes off handſomly by degrees, and her tuck not lying too low.

Bad run, when the tuck of a ſhip lies too low, it hinders the paſſage of the water to the rudder, and therefore ſhe cannot ſteer well, nor keep a good wind, nor make any good way thro' the ſea; but will be ſtill falling to leeward.

S

SEEL ſignifies much the ſame as *heel*; for as it is called *heeling*, when a ſhip lies down conſtantly or ſteadily on one ſide; ſo it is called *ſeeling*, when ſhe tumbles on one ſide violently and ſuddenly, by reaſon of the ſea's forſaking her, that is, the waves leaving her for a time in a rolling ſea.

Lee ſeel; that is, when the ſhip tumbles to *Leeward*. In this, even in a ſtorm, there is not much danger, for the ſea will preſently right her up again: But in caſe a ſhip *ſeels*, or rolls to *windward*, then there is fear of her coming over too ſhort or ſuddenly, and ſo in danger of being foundered, by the ſea's breaking right into her; or at leaſt having ſome of her upper-works carried away.

SET; to obſerve on what point of the compaſs the ſun, a ſhip, or any head-land bears, is call'd *ſetting the ſun, land,* &c.

SHEER; that is, to ſwing too and again.

The ſhip-ſheers; that is, goes in and out, and not right forward, either by not ſteering ſteadily, or by means of the ſwift running of the tide, *&c.* In ſuch caſe, they ſay, *ſhe ſheers*, or *goes ſheering*.

SHEATS, are ropes bent to the clew of the ſails; ſerving in the lower ſails, to hale aft, or round off the clew of the ſails; but in top-ſails, their uſe is to hale home, that is, to bring the clew of the ſail cloſe to the yard arm.

Standing part of the ſheat, is that part of it which is made faſt to the ring of the ſhip's quarter.

Over hale the ſheat; that is, hale upon the ſtanding part of the ſheat.

To hale aft the main ſheats, is in order to make the ſhip keep by a wind.

To hale aft the fore ſheats, is that the ſhip may fall off from the wind.

Eaſe the ſheat; that is, veer it, or let it go out gently.

Let fly the ſheat; that is, let it go all at once, and run out as faſt as it can; then the ſail will hang looſe, and hold no wind.

Tally the ſheats; that is, hale aft the ſheats of the main and fore ſail.

Flown ſheats. A ſhip is ſaid to ſail with *flown ſheats*, when her ſails are not haled home, or cloſe to the blocks.

The ſheats are flown; that is, they are let looſe, or to run as far as they will.

Falſe ſheat, is a rope bent to the clews of the main and fore-ſail, above the ſheat block, to ſuccour and eaſe the ſheat in a violent guſt of wind.

To SHIVER or *Shake* a ſail, is to bring the yard in a line with the wind.

SHOT *of a cable*, is the ſplicing of two cables together, that a ſhip may ride ſafe in deep waters and great roads: For a ſhip will ride eaſier by one ſhot of a cable, than by three ſhort cables out a head.

To SOUND, or *ſounding*, is to try the depth of water by a line and plummet, called a

Sounding-line; that is, a line by which ſeamen find where the ſhip may ſail by the depth of the water. It is generally about 20 fathom in length, and mark'd at two fathom next the lead, with a piece of black leather; at three fathom the like, but ſlit; at five fathom with a piece of white cloth; at ſeven fathom with a piece of red, &c. with ſome ſuch diſtinction all along. This line may be uſed when the ſhip is under ſail; which cannot be done ſo well with the *deep ſea-line*, in uſing of which the ſhip is uſually brought upon the back-ſtays.

SPOOMING, or *Spooning*; when a ſhip being under ſail in a ſtorm at ſea cannot bear it, but is forc'd to put right before the wind, without any ſail; then they ſay, the ſhip *ſpooms*: So that if a ſhip will neither *try*, nor *hull*, then they *ſpoon*; that is, put her right before the wind.

Spooming with the fore-ſail; that is, when in ſpooming there is danger that the ſhip may bring her maſts by the board with her rolling, or ſeek under water, and ſo founder; then it is uſual to ſet up the fore-ſail, to make her go the ſteadier, eſpecially if there be ſea-room enough.

STARBOARD, is the right ſide of the ſhip, or the right hand; as larboard-ſide is the left.

Starboard the helm, or *helm a ſtarboard*, in conding a ſhip, is to put the helm to the right ſide of the ſhip, or to put the helm a-ſtarboard, to make the ſhip go to the larboard; for the ſhip always ſails contrary to the helm.

STAYING *a ſhip*, or *to bring a ſhip upon the ſtays*, is in order to her tacking; and is done thus,

At the ſame time, *bear up the helm*, *let fly the fore-ſheat*, *let go the fore-bowline*, *brace the weather-brace of the fore-ſail*. The ſame is alſo done to the *top-ſail* and *top-gallant-ſail*, only their ſheats muſt be kept faſt. If the ſprit-ſail be out, then *let go the ſprit ſail ſheat*, with the *fore-ſheat*, and *brace the weather-brace*.

But the tacks, ſheats, bracings, and bowlines of the main-ſail, main-top-ſail and mizzen, are not altered.

And when the wind comes in at the *bow*, which before was the *lee-bow*, it drives all the ſails backwards againſt the ſhrowds and maſts; ſo that the ſhip makes no way forward, but drives with her broad ſide. Thoſe are accounted the beſt ſhips, which will *ſtay* with the feweſt ſails.

STEER. *To ſteer a ſhip*, is to guide or direct her courſe by the helm. There are three kinds of direction to *ſteer* by, *viz.*

1. By any *mark* on the *land*, ſo as to keep the ſhip even by it.

2. By the *compaſs*; which is to keep the ſhip's head upon ſuch a rumb, or point of the compaſs, as beſt leads to the deſigned port.

3. To *ſteer* as one is bidden, or conn'd; which is the duty (in great ſhips) of him that is taking his turn at the helm: And he is reckon'd the beſt *ſteers-man*, that uſes the leaſt motion in putting the helm over to and again, and that keeps the ſhip beſt from making *yaws*, that is, from running in and out.

STEERAGE, is that part of the ſhip next below the quarter-deck, before the bulk-head of the great cabin: 'Tis here, in moſt ſhips of war, ſtands the ſteers-man, or he that guides the helm or rudder of the ſhip.

STEM *of a ſhip*, is that great timber, which comes compaſſing from the keel (wherein it is ſkarfed) up before the fore-caſtle. This *ſtem* guides the rake of the ſhip; and all the butt-ends of the planks forwards are fixed into it.

Falſe-ſtem, is fixed before the right one, when that is made too flat for the ſhip to keep the wind well; which defect is remedied by a *falſe ſtem*, that will make her rid more way, and bear a better ſail.

STEP *of the maſt*, or *capſtan*, in a ſhip, is that piece of timber whereon the maſt or capſtan ſtands at bottom.

STERN *of a ſhip*, is properly the outmoſt part of a ſhip abaft; though generally ſpeaking, it is all the hindermoſt or aftmoſt part of a ſhip.

Stern-poſt, is a great timber let into the keel, at the ſtern of the ſhip, ſomewhat ſloping, into which are faſten'd the after-planks; and on this poſt hangs the rudder, by its pintles and gudgeons.

T

TACK, is a great rope with a whale knot at one end, which ſeiz'd into the clew of the ſail, is reev'd through the cheſs-trees, and then is brought through a hole in the ſhip's ſide. It ſerves to carry forward the clew of the ſail, to make it ſtand cloſe by a wind; the *tacks* of a ſhip are uſually belay'd to the bitts, or elſe there is a chevil or cleat on purpoſe to faſten them; they belong only to the main-ſail, foreſail, and mizzen. When the ſails are to be trimmed, ſo as to ſtand cloſe to a wind, the main, fore and mizzen *tack* are brought cloſe by the board, and over-haled as forward as they can be; the bow-lines are ſo alſo on the weather-ſide, the lee-ſheats are haled cloſe aft; as alſo the lee-braces of all the ſails are likewiſe braced aft, and the top-ſails are braced and govern'd as the ſails to which they belong.

Hale aboard the tacks; that is, bring the *tack* down cloſe to the cheſs-trees.

Eaſe the tack; that is, ſlacken it, or let it go, or run out.

Let riſe the tack, that is, let it go all out.

The ſhip ſails, or *ſtands cloſe upon a tack*; that is, cloſe by the wind.

To tack about, is to bring the ſhip's head about, ſo as to lie the contrary way; which is perform'd thus: Frſt make the ſhip ſtay; and when ſhe is ſtay'd, they ſay ſhe is *pay'd*; then *let riſe and hale*; that is, let the lee-tack riſe, and hale aft the ſheats and ſo trim all the ſails by a wind as before; for they caſt off that which was before the weather-bowline, and ſet up the other taught. And thus they do alſo by all ſheats, braces and tacks, which a ſhip that is trimm'd by a wind muſt have.

TACKLES, are ropes running in three Parts, having a pennant with a block at one end, and a block with a hook at the other end.

TAUGHT, or *Taut*, ſignifies ſtiff or faſt; as *hale taught a rope*, that is, ſet it ſtiff or ſtrait.

TILLER, the ſame with the helm of a ſhip: It is moſt properly uſed in a boat, where that which would be the helm of a ſhip, is call'd the *Tiller*, and ſerves for the ſame uſe.

TRANSOM, is a piece of timber that lies a-thwart the ſhip's ſtern, between the two faſhion pieces, directly under the gun-room port; and it lays out the breadth of the ſhip at the buttocks: As when a ſhip is built broad or narrow at her *tranſom*, ſhe is ſaid to have a broad or narrow buttock.

TRIM *of a ſhip*, is her beſt poſture, proportion of ballaſt, and hanging of her maſts, &c. for ſailing.

To find the trim of a ſhip; that is, to find the beſt way of making any ſhip ſail ſwiftly, or how ſhe will ſail beſt: This is done either by trying her ſailing with another ſhip, ſo many glaſſes trimm'd a-head, ſo many a-ſtern, and ſo many upon an even keel; or elſe by eaſing of her maſts and ſhrowds; ſome ſhips ſailing much better when ſlack, than when they are taught. But this depends very much upon experience and judgment, and the ſeveral trials which the commander and other officers may make aboard.

TRIP; as *the ſhip goes with her top-ſails a-trip*; that is, when ſhe carries her top-ſails hoiſted up to the higheſt, when it blows not too hard, but a gentle or loom-gale, as it is called.

TRY; *as the ſhip lies a-try under a main-ſail, or main courſe*; that is, when ſhe has no other ſails abroad; the tacks haled cloſe a-board, the bowlines ſet up, the ſheats haled cloſe aft, and the helm tied down cloſe by the board, and ſo ſhe is let lie in the ſea. But at this time if ſhe be upon a wind, ſhe uſually makes her way good, near three points before the beam.

To try under a Mizzen; this is done when it blows ſo hard, that they cannot maintain the main-ſail; that is, cannot bear the main-ſail out; and then if ſhe lie cloſe by the wind, ſhe will make her way about two points before the beam.

But if ſhe *try* under a main-ſail and mizzen, ſhe will make her way good about four points before the beam.

If a ſhip will neither *try* nor *hull*, then *ſpoom*; that is, put her right before the wind.

V

VEER; as, *veer out a rope*, that is, let it go by hand, or let it run out of itſelf.

Veer, is alſo uſed in reference to the wind; as *the wind veers*; that is, when it changes often, and ſuddenly, or ſhifts from point to point.

VEERING, as *the ſhip goes veering*; that is, ſhe goes at large, neither by a wind, nor directly before it; but between both; which is alſo call'd *quartering*.

VIOL, a kind of hawſer, made uſe of to purchaſe in the cable, when the main capſtan cannot do it; becauſe the ground in which the anchor is fix'd, is too ſtiff; or elſe the ſea runs too high, ſo that they cannot weigh it. In which caſes they take a hawſer, and opening one end of it, they put therein nippers, of about eight fathoms from each other, wherewith they bind this hawſer faſt to the cable, and then bring it to the jear capſtan, to heave upon it. And this will purchaſe far more than the main capſtan can.

W

WAKE *of a ſhip*, is the ſmooth water a-ſtern, when ſhe is under ſail. This ſhews the way ſhe has gone in the ſea, whereby the mariners judge what way ſhe makes; for if the *wake* be right a-ſtern, they conclude ſhe makes her way right forwards; but if the *wake* be to leeward a point or two, then they conclude ſhe falls to leeward of her courſe.

The ſhip ſtays to the weather of her wake; that is, when in her ſtaying ſhe is ſo quick, that ſhe does not fall to leeward upon a tack; but that when ſhe is tacked, her *wake* is to the leeward; then it is a ſign that ſhe feels her helm very well, and is quick of ſteerage.

WARPING, is to hale a ſhip up by a hawſer, or any other rope, ſufficient for that purpoſe, with an anchor bent to it. This is uſed when a wind is wanting to carry a ſhip into, or out of a harbour.

Warp, ſo is the hawſer, or rope uſed to hale the ſhip up, called.

WAY *of a ſhip*; as, *To keep an account of the ſhip's way*, is one of the moſt neceſſary things in the practice of navigation; and the moſt approv'd method of doing this, is by the log and log-line. Which See.

Lee-way, or *leeward way*, is the angle made by the point ſteer'd upon, and the way of the ſhip; and ſince moſt ſhips are apt to fall a little to leeward of their courſe, it is neceſſary at all times in caſting up the log-board, to allow ſomething for the lee-way; as.

1. If the ſhip be upon a wind, allow one point for lee-way.

2. If the wind blow hard, and cauſe one top-ſail to be taken in, allow two points for lee-way.

3. If the wind blow ſo hard that both top-ſails are taken in, and the ſea run high, allow three points for lee-way.

4. If the fore-ſail be furl'd, and ſhe try under a main-ſail and mizzen, ſhe will make her way four points before the beam.

5. If ſhe try under a main-ſail only, ſhe will make her way near three points before the beam.

6. But if ſhe try under a mizzen only, ſhe will make her way about two points before the beam.

7. If ſhe lie a-hull, with all her ſails furl'd, ſhe will make her way one point before the beam.

Way aftward on, or *forward on*; that is, the rake or run of a ſhip. Which ſee.

WEATHER; *as*, *To weather a point*; that is, to paſs by it on the weather-ſide. *To weather a ſhip*; that is, to go to windward of her.

Weather-coyle; that is, when a ſhip has her head brought about, ſo as to lie that way which her ſtern did before, without looſing of any ſail, but only by bearing up the helm.

Weather-gage. See GAGE.

WHIP, or *Whip-ſtaff*, is a ſtrong ſtaff faſten'd into the helm of ſmall ſhips, for him that ſteers to hold in his hand, thereby to move the helm, and ſteer the ſhip.

WIND, is defined to be the ſtream or current of the air, which blows from ſome one of the two-and-thirty points of the horizon, or compaſs.

Windward; that is, nearer the riſe of the wind.

To have the Wind of a ſhip; that is, to be to windward of her.

Touch the Wind; that is, keep as cloſe upon the wind as poſſible.

The wind's eye; that is, directly againſt the wind.

WINDLASS, is an inſtrument in ſmall ſhips, placed upon the deck, juſt abaft the fore-maſt. 'Tis made of a piece of timber ſix or eight foot ſquare, in form of an axel-tree, whoſe length is plac'd horizontally upon two pieces of wood at the ends thereof, and upon which it is turned about by the help of handſpikes, put into holes made for that purpoſe. This inſtrument ſerves for weighing anchors, or hoiſting of any weight in or out of the ſhip; and will purchaſe much more than any capſtan, and that without any danger to thoſe that heave; for if in heaving the *windlaſs* about, any of the handſpikes ſhould happen to break the *windlaſs* would paul of itſelf.

Y

YARDS *of a ſhip*, are thoſe long pieces of timber made ſomewhat tapering towards each end, and fitted each a-thwart its proper maſt, with the ſails made faſt to them, ſo as to be hoiſted up, or lower'd down, as occaſion requires. They have their particular names from the maſts they belong to.

Yard-arm, is that half of the yard on either ſide of the maſt.

Brace the Yard, that is, traverſe aft the yard-arm, whoſe brace is haled.

Square the yards; that is, ſee that they hang right a-croſs the ſhip, and one yard-arm not traverſed more than another.

Top the Yards; that is, make the yards ſtand even; for to top the main and fore-yards, the clew-lines are the moſt proper; but when the top-ſails are ſtow'd, then the top-ſails ſheats will top them.

YAWS; as *the ſhip makes yaws*; that is, does not ſteer ſteady, but goes in and out when there is a ſtiff gale. And he that keeps the ſhip moſt from *yawing*, does commonly uſe the leaſt motion with the helm; and thoſe ſteer beſt.

AN APPENDIX,

Containing the

DESCRIPTION AND USE

Of a Compleat

SETT OR CASE of POCKET-INSTRUMENTS.

A COMPLEAT ſet of pocket-inſtruments (though ſometimes made according to particular direction) generally conſiſts of the following particulars, *viz.* 1. A large pair of compaſſes with one point made to take out, in order to receive in its place, either a drawing-pen, a port-crayon, or a dotting-wheel; according as you would deſcribe your circles or arches, with ink, black lead, &c. or only with dots. 2. A ſmaller pair of compaſſes for the exact taking of diſtances, or ſtriking obſcure arches, &c. in working geometrical problems. 3. A longer drawing pen, whoſe handle contains a protracting pin, and a ſocket to hold a pencil. 4. A parallel ruler. 5. A protractor, either ſemi-circular, or (as they are more commonly fitted up for caſes) in form of a parallelogram or long ſquare, for the conveniency of laying down on the back ſide thereof, ſeveral lines of equal parts, both ſimply and diagonally divided, with two or three lines of chords of different radii; and ſometimes all the ſeveral lines of the common plane ſcale are laid down thereon. 6. A ſector. Theſe caſes of inſtruments are made of ſeveral ſizes; but moſt commonly either of the length of four inches, four inches and a half, or ſix inches; this laſt ſize, though ſomewhat heavier for the pocket, are preferable in uſe, as the diviſions upon the ſector are more ſenſible, and conſequently their application in practice more exact.

Of the Compaſſes.

A pair of compaſſes is an inſtrument ſo well known, that it would be little leſs than ridiculous to waſte words in its deſcription; but a few directions in judging of their goodneſs, may probably be of ſervice. Obſerve therefore, 1. That the motion of the head be equal, that is, that in opening or ſhutting you find no ſudden jerks. 2. That the joints are well fitted, ſo that there be no ſhake in the application of any of the points. 3. That they be well filed and poliſhed. And, laſtly, That the ſteel points are cloſe join'd, equal and well tempered.

The uſe of a pair of compaſſes is as well known as their form; I ſhall therefore only obſerve that it is an inſtrument well adapted for taking diſtances, and deſcribing circles, or arches from a given center; which, as before was intimated, may be done either obſcurely, with the ſteel point; in ink, with the drawing pen point; in black lead, &c. with the crayon point; or by dots only, with the dotting wheel point; as the occaſion requires. Note, alſo, either of theſe points may be uſed to draw a ſtraight line along the edge of a ruler.

Of the longer drawing Pen, with the protracting Pin.

This inſtrument is compoſed of two ſteel blades fixed into a ſmall pillar of braſs, ſilver, &c. called the handle, one of theſe blades by means of a joint, may be made to open for the conveniency of cleaning, and by help of a ſmall ſcrew, they are eaſily ſet to the proper thickneſs of the line you would draw; the ink being inſerted into the cavity betwixt the blades, with a common quill-pen; ſo that if the blades are well fitted and poliſhed, the line they draw will be exceeding ſmooth and even, which cannot be ſo certainly done with a common pen. The uſe therefore of this part of the inſtrument is only to draw ſtraight lines, which generally ſhould be drawn very fine. The other part, which is call'd a *protracting pin*, is a ſhort piece of poliſhed ſteel wire, fix'd in the lower end of the upper part of the handle, where it ſcrews into the lower part to ſave the point, which is made very fine, from damage, when not uſed; its uſe is to ſet off angles from the protractor, as ſhall be hereafter ſhewn in deſcribing that inſtrument.

Of the parallel Ruler.

This inſtrument conſiſts of two equal rulers, ſo connected to each other, by moveable croſs-pieces of braſs or other metal, either fix'd parallel to each other, and lying aſlant when the two rulers are cloſed, or croſſing each other with a joint in the middle, that to whatever degree the rulers are opened, they are ſtill kept in a true parallel poſition to each other; by which means one part being ſet true upon any line, another line may be drawn by the other part of the ruler exactly parallel to that whereon the firſt is placed: Which expedient is of great uſe in delineating moſt ſorts of draughts, particularly in plans of architecture, both military and civil; and in reducing a multangular figure to either trapezia or triangles, for the more accurate and ready finding the content.

Of the Protractor.

Fig. 1. The protractor is commonly a ſemicircle, on whoſe chord or diameter is mark'd its center, and whoſe arch is divided into 180 equal parts, called degrees; being the half of 360, which every whole circle is ſuppoſed to be divided into (See fig. 1. at the end of the Appendix.) But for caſes of inſtruments, it is frequently made in form of a parallelogram, upon three ſides of which the ſame diviſions are laid down from a center, mark'd on the fourth or diameter (as in the plate fronting the title, in the figure mark'd C). Every 10 of theſe degrees are number'd, and every fifth diſtinguiſhed with a longer mark than the others, for the greater eaſe in reckoning. They are uſually number'd both ways, *viz.* from right to left, and from left to right, for the more readily laying down an angle from either end of a given line. The ſide to be applied to the paper is made flat, and that whereon the degrees are mark'd is filed ſo ſloping, as to render the edges thin for the greater exactneſs in ſetting off, or meaſuring an angle; which are all the uſes of this inſtrument as a protractor, and perform'd in the following manner.

1. If it was required to lay down an angle of 60 degrees, from the point A of the line AB. Lay the diameter of the protractor on the line AB, ſo that the center may fall upon the point A, then with your protracting pin make a mark in your paper exactly againſt the number 60 upon the limb of your protractor; ſo ſhall a line drawn through the ſaid mark to the point A, form an angle of 60 degrees. *Fig.* 2.

2. If it be required to find the quantity of an angle given, as in the foregoing figure the angle BAC. Lay the diameter of the protractor on the line AB, ſo that the center may fall exactly upon the point A; then ſhall the degree on the limb cut by the line AC, ſhew the quantity of the angle, as before, 60 degrees.

On the reverſe of a protractor, when made in form of a parallelogram (*Vide* figure mark'd D in the plate fronting the title) are uſually laid down ſeveral ſcales, or lines of equal parts of different proportions, that is, of 45, 40, 35, 30, 25, and 20 parts to an inch, diſtinguiſh'd by the ſaid numbers prefixed, and lines of chords of different radii; beſides theſe, there is another commonly called a diagonal ſcale, divided into quarters of an inch, with a half inch at one end, which half inch, and the extream quarter at the other, are both divided into ten equal parts at their outward edges, and diagonal lines drawn from the beginning, firſt, ſecond, *&c.* diviſion at one edge of each to the firſt, ſecond, third, *&c.* at the other, and the whole ſcale divided into ten equal parallel parts, whereby each of theſe extreams is divided into 100 equal parts; and if this ſcale be laid down within the vacant ſpace on the face of the protractor (as in fig. C) there may be room on the reverſe (as in fig. D) for all the lines uſually placed on the inſtrument, called the *plane ſcale*, ar well as the before-mentioned lines of equal parts, *&c.* In giving therefore the conſtruction and uſe of the plane ſcale, I ſhall ſufficiently deſcribe all the lines uſually laid down on the reverſe of a protractor, and ſhew their ſeveral uſes and application in practice. But firſt I ſhall ſhew the uſe of the ſeveral ſcales or lines of equal parts, both as they are ſimply, and diagonally divided.

Of the Uſe of Scales, or Lines of equal Parts.

1. *Simply divided, Vide* fig. D. A line of equal parts is no more than a ſcale of meaſure in miniature, for laying down by way of plan, lengths taken by any known meaſures, as chains, yards, feet, *&c.* each part on the ſcale anſwering accordingly to one chain, one yard, or one foot, *&c.* The plan therefore will be the greater or leſs, as the ſcale uſed contains more or leſs parts in the ſpace of an inch. Note, the firſt diviſion on every ſcale is ſubdivided into 10 equal parts, theſe ſmaller diviſions are the parts to be underſtood, when we

ſay it is a ſcale of 20 or 30, &c. If, therefore, theſe leſs diviſions be taken as units, and each repreſent one league, one mile, one chain, one yard, or one foot, &c. the larger diviſions will conſequently be come tens, tho' numbered with ſingle figures; ſo that to ſet off 36 leagues, miles, chains, yards or feet, &c. extend the compaſſes from 3 of the larger diviſions, to 6 reckoned backwards upon the ſmaller, and that extent laid down on your plan, ſhall accordingly repreſent 36 leagues, miles, chains, yards or feet, actually meaſured in the thing repreſented. To adapt theſe ſcales to feet meaſure, you will likewiſe find the firſt diviſion of each duodecimally divided, above the decimal diviſion, the halves and quarters of which are diſtinguiſhed by longer marks than the reſt, which are generally only dots; ſo that to lay down any number of feet and inches, as ſuppoſe 8 feet, 9 inches, extend the compaſſes from 8 of the large diviſions, to 9 of the upper ſmall diviſions; and the ſaid extent laid down on your plan, ſhall repreſent by whatever ſcale it is taken, from 8 feet, 9 inches, in length actually meaſured. This may ſuffice for thoſe ſcales which are only ſimply divided.

2. *Diagonally divided*, *Vide* fig. C. The firſt of theſe larger diviſions of the half and quarter inch ſcales, being by the parallel and diagonal lines accurately divided into 100 equal parts, if the ſcale contains 7 or 12 of the larger diviſions, any length to 700 or 1200 may thereby be more exactly taken off, than by thoſe ſimply divided into 10 and 12 parts as above.

The conſtruction of theſe diagonal ſcales is in this manner. Firſt draw eleven parallel lines at equal diſtances, (*vide* fig. C) the whole length of which being divided into a certain number of equal parts, according to the length of the ſcale, by perpendicular parallels; let the firſt diviſion be again ſubdivided into ten equal parts, both above and below; then drawing the ſeveral oblique lines from the firſt perpendicular below, to the firſt ſub-diviſion above, and from the firſt ſub-diviſion below to the ſecond ſub-diviſion above, &c. the whole firſt ſpace ſhall thereby be exactly divided into 100 equal parts; for as each of the ſub-diviſions is one tenth part of the whole firſt ſpace or diviſion, ſo each parallel above it is one tenth of ſuch ſub-diviſion, and conſequently one hundredth part of the whole firſt ſpace, and if there be 10 of the larger diviſions, one thouſandth part of the whole ſcale. If therefore the larger diviſions be accounted as units, the firſt ſub-diviſions will be tenth parts of an unite, and the ſecond ſub-diviſions mark'd by the diagonals, upon the parallels, hundredth parts of an unit; if the larger diviſions be reckoned tens, the firſt ſub-diviſions will be units, and the ſecond tenth parts: And if the larger diviſions be accounted as hundreds, the firſt ſub-diviſions will be tens, and the ſecond units. The numbers therefore 576, 57.6, 5.76 are all expreſſible by the ſame extent of the compaſſes, *viz.* ſetting one foot in number 5 of the larger diviſions, extend the other along the ſixth parallel, to the ſeventh diagonal: For if the 5 larger diviſions are taken for 5 hundred, 7 of the firſt ſub-diviſions will be 70, which upon the ſixth parallel, taking in 6 of the ſecond ſub-diviſions, or 6 units, makes the whole number 576. Or, if the five larger diviſions be taken for 5 tens or 50, ſeven of the firſt ſub-diviſions will be 7 units, and the 6 ſecond ſub-diviſions included upon the ſixth parallel, will be ſix tenths of an unit. Laſtly, if the 5 larger diviſions be only eſteemed as five units, then will the 7 firſt ſub-diviſions be ſeven tenths, and the 6 ſecond ſub-diviſions ſix hundredth parts of an unit. And this I think may be ſufficient to ſhew the uſe both of the ſimple and diagonal ſcales of equal parts: I now proceed to

The Conſtruction and Uſe of the Plane Scale.

Having deſcribed the circle ABCD, divide it into four quadrants, by the diameters AB and CD, croſſing each other at right angles. *Fig.* 3.

1. To project the line of *Tangents.* From the end C of the diameter CD, erect the perpendicular CG; then dividing the arch CB into nine equal parts; from the center E, through the ſeveral diviſions of the arch, draw lines till they cut the perpendicular CG, which will thereby become a line of tangents.

2. For the line of *Semi-tangents.* Lines drawn from the point D, through the ſame diviſions upon the arch CB, will divide the radius BE, into a line of ſemi-tangents. The ſemi-tangent is here to be underſtood as the tangent of half the arch; and by the 20th of the 3d of *Euclid*, it is prov'd, that an angle at the center, is the double to one at the circumference.

3. For the *Secants.* Since the lines drawn from the center through the ſeveral diviſions of the quadrant CB, to form the tangents, are the ſecants of thoſe reſpective arches, transfer thoſe lengths to the line EB continued to F, and the line EF will be a line of ſecants.

4. For the *Sines*. From the ſeveral diviſions of the arch CB, let fall perpendiculars upon the radius CE; ſo ſhall the radius CE be divided into a line of ſines, which is to be numbered from E to C for the right ſines, and from C to E for the verſed ſines. Note, the verſed ſines may be continued to 180 degrees, if the ſame diviſions be transferr'd on the other ſide of the center E.

5. For the *Chords*. The arch CB being divided into 9 equal parts, in the points 10, 20, 30, *&c.* if therefore you imagine lines drawn from C, to the ſaid ſeveral diviſions, they will be the chords of their reſpective arches. Setting therefore one foot of your compaſſes in the point C, and tranſferring the ſeveral lengths C 10, C 20, C 30, *&c.* to the line CB, and the line CB ſhall thereby be made a line of chords.

Note, Theſe ſeveral lines (which in the figure are drawn but to every 10 degrees) might be conſtructed to every ſingle degree, if the circle were made large enough to admit of 90 diſtinct diviſions in the arch of its quadrant.

6. A line of *Rhumbs* is thus conſtructed. Divide the arch DB into 8 equal parts, in the points 1, 2, 3, 4, *&c.* then ſetting one foot of the compaſſes in D, transfer the ſeveral diſtances D 1, D 2, D 3, *&c.* from the arch to the line DB, by which means you will form a line of rhumbs, each of which will anſwer to an angle of 11° 15′.

7. For the line of *Longitude*. Divide the radius EA into 60 equal parts (becauſe 60 miles make a

degree of longitude under the equator) marking every ten with their proper number; from theſe diviſions let fall perpendiculars upon the arch AD, then having drawn the line AD, with one foot of the compaſſes in A, transfer the ſeveral diſtances where the perpendiculars cut the arch, to the line AD; which ſhall thereby be made a line of longitude.

Now if the ſeveral lines with their reſpective diviſions thus projected, in fig. 3. be transferr'd to the ſcale mark'd D, in the plate fronting the title, where they are diſtinguiſh'd by their proper names; and thereto be added lines of equal parts, as before deſcrib'd, the inſtrument called the *Plane Scale*, will thereby be form'd.

But as upon the reverſe of ſome protractors, beſides the ſeveral lines already explain'd, there are two other lines laid down, *viz.* the line of latitude, and the line of hours; I ſhall likewiſe ſhew the method by which they are projected.

Projection of the Lines of Latitude, and of Hours.

1. To project the line of *Latitude*. In the ſame diagram (*viz.* fig. 3.) the radius CE being already divided into a line of ſines, laying a ruler from the point B, through each of the ſaid diviſions, mark the points cut on the oppoſite arch AC, with the numbers 10, 20, 30, *&c.* then having drawn the right line AC, with one foot of your compaſſes in A, transfer the ſeveral interſections of the arch, to the ſaid right line, which will thereby become a line of latitude, and may accordingly be laid down on your Scale.

2. To project the *Line of Hours*. Draw the tangent IK, equal and parallel to the diameter CD; and divide half the arch of each quadrant AC and AD, from the point A, into three equal parts, which will be 15 degrees each part, for the degrees of every hour from 12 to 6; each of which parts are to be again ſub-divided into halves and quarters, *&c.* then drawing lines from the center of the circle, through each of theſe diviſions and ſubdiviſions, till they cut the tangent line IK, the ſaid tangent line will thereby be divided into a line of hours.

3. To theſe may be ſtill added, another line, applicable to the ſame uſe, *viz.* the line of *Inclination of Meridians*, which is projected in the ſame manner as the line of hours; only divided into degrees inſtead of time, every 15 degrees being equal to an hour.

The uſes of the ſeveral lines thus laid down on the ſcale D, *from the foregoing Projections, are as follow.*

1. The *Tangents*, *Semi-tangents*, and *Secants*, ſerve to find the centers, and poles of projected circles, in the ſtereographical projection of the ſphere, *&c.*

2. The *Sines* ſerve for the orthographical projection of the ſphere, *&c.*

3. The line of *Chords* ſerves either to ſet off an angle from a given point in any right line; or to meaſure the quantity of an angle already

laid down. The firſt is done by opening your compaſſes to the extent of 60 degrees upon the line of chords (which is always equal to the radius of the circle of projection) and ſetting one foot in the angular point, with that extent deſcribing an arch; then taking the quantity of the angle required, between the feet of your compaſſes from the ſame chord-line, ſet it off from the given line upon the arch deſcribed; ſo ſhall a right line drawn from the given point, through the point mark'd on the arch, form the angle required. Thus to lay down from the point A of the line AB, an angle of 40 degrees, taking the extent of 60 degrees between the feet of your compaſſes from the line of chords, ſtrike the arch CD, then ſetting off upon the ſaid arch from D to C, the extent of 40 degrees taken from the ſaid line of chords, from the point A draw the line AC, to paſs thro' the point C, ſo ſhall the lines AB and AC form an angle of 40 degrees. The latter is done by deſcribing as before, an arch with the extent of 60 degrees, and then taking the extent betwixt the lines which form the angle upon the ſaid arch; that extent meaſur'd upon the ſame line of chords, will ſhew the quantity of the angle. *Fig.* 4.

4. The line of *Rhumbs* ſerves with more readineſs than the line of chords, to lay down or meaſure the angle of a ſhip's courſe in navigation. For example, ſuppoſe a ſhip's courſe being N.N.E. it is required to lay down the angle. Draw the line AB for the meridian, then with 60 degrees of the chords, deſcribe from the point A, the arch BC; and as N.N.E. is the ſecond rhumb from the north, open your compaſſes to the ſecond rhumb, and lay *Fig.* 5.

lay off the extent upon the arch BC, ſo ſhall a right line from the point A through the point C, give the angle of the courſe BAC. Or if it were required to find the quantity of the angle of a ſhip's courſe BAC; having deſcribed the arch BC, with 60 degrees of the chords, take the diſtance of the lines upon the ſaid arch between the feet of your compaſſes, which meaſur'd upon the line of rhumbs, will ſhew the quantity of the angle.

5. The line of *Longitude* being laid down on the ſcale, contiguous with a line of chords of the ſame radius, number'd the contrary way, ſhews by inſpection, how many miles there are in a degree of longitude, in each parallel of latitude; accounting the latitude upon the line of chords, and the miles of longitude upon the line of longitude. Thus in the latitude of 30 degrees, it appears that 52 miles make a degree of longitude; in the latitude of 60 degrees, 30 miles make a degree; and in the latitude of 80 degrees, 10 miles make a degree, *&c.*

6. The two lines of *Latitudes* and *Hours*, are uſed conjointly, and ſerve very readily to mark the hour-lines in the conſtruction of dials, on any kind of planes horizontal or vertical.

As an inſtance of which I ſhall give one example of an horizontal dial for the latitude of *London*, *viz.* 51° 32′.

To conſtruct an horizontal Dial, by the Lines of Latitude and Hours; for the Latitude of 51° 32′.

Firſt, draw the line E W of a convenient length, for the ſix a clock line, and at right angles thereto, the line NS for the meridian, or 12 a clock line, of a breadth equal to the thickneſs of the ſtile; the interſection of which lines, *viz.* the point A will be the center of your Dial: Then taking 51° 32′ (the latitude of the place) from the line of latitude, with one foot of your compaſſes in A, ſet off that extent on both ſides, from A to E, and from A to W; then with the whole length of the line of hours between your compaſſes, ſet one foot in E, and croſs the meridian line with the other; do the ſame on the other ſide from W, and draw the lines NE and NW, then taking between your compaſſes from the line of hours, the diſtance from the beginning thereof to I, lay down that diſtance both ways from N to 1, and from N to 11, likewiſe from E to 5, and from W to 7; ſet off alſo the diſtance from the beginning of the line to II on the line of hours, both from N to 2 and 10, and from E to 4, and W to 8; and laſtly, lay down the diſtance from the beginning of the line of hours to III, from N to 9, and from N to 3, which ſaid diſtance will likewiſe reach from E to 3, and from W to 9. Thus having divided your trigon into its proper diſtances, lines drawn from the center A of the dial, through theſe ſeveral diviſions, will mark the reſpective hour points on the limb of the dial, whether its figure be ſquare or round; and for the hours before 6 in the morning, and after 6 at night, they are eaſily found by continuing the lines of the oppoſite hours through the center. *Fig.* 6.

Note, The ſtile, which is generally a thin plate of braſs, muſt make an angle with the plane equal to the latitude of the place; the angular point being fix'd juſt at the center A, and the ſtile ſtanding upon the meridian line, at right angles with the plane of the dial.

Of the Sector.

The *Sector* is a mathematical inſtrument, taking its name from a geometrical figure, which *Euclid* thus defines; a ſector is a part of a circle, bounded by two radii, or ſemi-diameters, and part of the circumference, *viz.* the included arch. As an inſtrument, it conſiſts of two equal legs, moveable about a joint like the common carpenter's rule; which being each of the length of 6 inches (though they may be made of any other determinate length, as in the figures mark'd A and B in the plate fronting the title, they are of 4 inches and a half) when quite open, they form an exact foot rule; and may be uſed as ſuch in taking dimenſions, being like other common rules, divided into inches and parts.

The lines commonly laid down on the faces of this inſtrument to be uſed ſector-wiſe, are as follow, *viz.* upon one face (that mark'd A in the print.) 1. Tbe lines of *Lines*, or length, conſiſting of equal parts. 2. The lines of *Chords*. 3. The lines of *Secants*. 4. The lines of *Polygons*. On the other face (marked B in the print.) 1. The lines of *Sines*. 2. The lines of *Tangents* to 45 degrees. 3. Other lines of *Tangents* to a leſs radius, to ſupply the defect of the former, from 45 degrees to about 75 degrees.

Note, If the lines of leſs tangents, and the lines of ſecants, be projected from a radius $\frac{1}{4}$ of the larger lines, and laid down upon the inſtrument to the ſame angle, then without any alteration in the opening of the legs, any extent taken on the lines of leſſer tangents or ſecants, 4 times repeated, will give the proper tangent or ſecant, to the radius of the larger lines.

Theſe ſeveral lines are projected and divided as the ſame lines upon the plane ſcale; but laid down upon the ſector (all except the lines of polygons) ſo as that they may all make one certain angle, that is, to whatever degree the ſector is opened, the diſtance will be the ſame betwixt 100 and 100 on the lines of lines, 90 and 90 on the lines of ſines, 60 and 60 on the lines of chords, and 45 and 45 on the lines of tangents; and the angle each of theſe lines makes with its correſponding one, when the ſector is quite ſhut, is eaſily ſeen, by the extent of the ſaid diſtance taken from the center of the joint (called the center of the ſector) laterally on either line of chords. The lines of lines are each divided into 100 equal parts, each of which are again ſub-divided into halves and quarters, if the legs are of ſufficient length; and with the lines of ſines, chords and tangents, are each extended to the length of the radius of the circle from which they are projected; that is, the lines of ſines to 90 degrees, the lines of chords to 60 degrees, and the lines of tangents to 45 degrees; each being number'd at every 10 degrees from the center to their ſeveral ends, where they are mark'd with the initial letters of their reſpective names.

Note, The correſpondent parallels of the ſeveral lines are intended for the better diſtinguiſhing the ſeveral diviſions upon each.

The lines of ſecants, and of leſs tangents, are each projected from a circle, whoſe radius is $\frac{1}{4}$ of that from which the other lines are projected; and beginning at the length of that radius from the center of the inſtrument, run to about 75 degrees. The tangents beginning at 45, where the larger lines of tangents end, have their degrees diſtinguiſhed by the numbers 45, 50, 60, 70, 75, and the ſecants with the numbers 10, 20, 30, *&c.* to 75; and both are mark'd for diſtinction ſake, with the ſmall initial letters of their names.

The lines of polygons are laid down from the center of the joint, very near the inward edges of the inſtrument, and are numbered backwards from the ends towards the center, with the figures 4, 5, 6, *&c.* to 12, which comes within about three inches of the center.

Theſe are all the lines which are uſually laid down on this inſtrument to be uſed ſectorwiſe.

The other lines which are placed upon, and parallel to the outward edges on both faces, and uſed as on common ſcales, the ſector being quite opened, are, on the edge itſelf, a line of *Inches*, with each inch ſub-divided into 10 equal parts; and on the faces, the line of *Numbers*, commonly called *Gunter's Line*, with the lines of *Artificial Sines* and *Tangents*; alſo ſometimes a line of *Hours*, with a line of *Chords*, and a line of *Latitudes*,

tudes, with a line of *Inclination of Meridians*, each being diſtinguiſhed with its proper letter.

Of the Foundation and general Uſe of the Sector.

The foundation and general uſe of the ſector depends upon the 4th propoſition of the 6th book of *Euclid*, where it is prov'd, that the homologous ſides of ſimilar triangles, are proportional to each other. Suppoſe therefore the lines AB, AC, to repreſent any pair of lines upon the ſector, particularly the lines of lines, making an angle BAC, with each other. If then, the line BC be drawn, and A a, A b taken equal, and the line a b alſo drawn; as Aa, or Ab is to AB, or AC, ſo will a b be to BC. Whence if the lines Aa, AB, be the half, the third, the fourth, *&c.* of the lines AB, AC; the line a b will accordingly be the half, the third, the fourth, *&c.* of the line B C. As ſuppoſe A B, or AC be 100, and Aa, or Ab 50; then if BC be 60, a b ſhall be 30. Hence it follows, that if the lines AB, AC, repreſent the lines of chords, ſines or tangents, that is, if the line AB, or AC be the radius, and the line A a or A b the chord, ſine or tangent, of ſome propoſed number of degrees to the ſaid radius AB; then the line a b will be the chord, ſine or tangent of the ſame number of degrees to the radius BC.

Fig. 7.

And here note, that lines taken upon the ſector, are diſtinguiſhed by the terms *lateral* and *parallel*; thoſe being call'd lateral, which are found upon the ſides of the inſtrument, as AB AC; and parallel, are ſuch extents as are taken from one leg to the other, at equal diſtances from the center of the joint, as BC, a b.

If therefore it be required to find the chord, ſine or tangent of 20 degrees, to a radius of 5 inches; open the ſector ſo that the diſtance from 60 to 60 on the lines of chords, may be equal to 5 inches; then will the parallel diſtance between 20 and 20 on the lines of chords, be the chord of 20 degrees, to a radius of 5 inches; ſo likewiſe the diſtance between 20 and 20 on the lines of ſines, and between 20 and 20 on the lines of tangents, will be the reſpective ſine or tangent of 20 degrees, to the ſaid radius of 5 inches.

If a chord of more than 60 degrees be required to any aſſign'd radius; as ſuppoſe the chord of 80 degrees; open the ſector as before directed to the radius given, and with the ſaid radius, deſcribe an arch ſufficiently large, as AD; then taking the chord of half the number of degrees, *viz.* 40, lay it off twice upon the ſaid arch, *viz.* from A to B, and from B to C, or which may be better, firſt lay off the radius from A to E, and then the chord of the exceſs, *viz.* of 20 degrees, from E to C, ſo ſhall a line drawn from A to C, be the required chord of 80 degrees.

Fig. 8.

If a tangent of more than 45 degrees be required, as ſuppoſe the tangent of 70 degrees, it muſt be taken from the lines of leſs tangents, which if not laid down to the ſame angle as the larger lines, as in moſt ſectors they are not, then muſt the ſector be ſo opened, that the diſtance between 45 and 45 on the ſaid leſs tangents, may be equal to the given radius; ſo ſhall the diſtance between 70 and 70 upon the ſaid lines of leſs tangents, be the tangent of 70 degrees, to the radius given. But if the lines of the leſſer tangents are made (as they ſhould be) to $\frac{1}{4}$ of the radius of the larger, and laid down to the ſame angle, then the tangent of any required number of degrees, either more or leſs than 45, may be taken off without any alteration in the opening of the ſector; for in the inſtance above of 70 degrees, the diſtance between 70 and 70 on the line of leſſer tangents, 4 times repeated, will be the tangent of 70 degrees, to the radius ſo ſet off between 45 and 45 on the line of larger tangents.

To find the ſecant of any propos'd number of degrees to a given radius, as ſuppoſe the ſecant of 60 degrees, to a radius of two inches; open the ſector to the diſtance of 2 inches between 0 and 0 on the lines of ſecants; ſo ſhall the diſtance between 60 and 60 upon the ſaid lines, be the ſecant of 60 degrees, to the radius of two inches: Or, if according to the above remark on the tangents, the lines of ſecants are projected to $\frac{1}{4}$ of the larger radius, and form the common angle; the diſtance between any propoſed point, 4 times repeated, will give the proper ſecant to the radius the larger lines are open'd to.

If the contrary of any of theſe operations be required, that is, if a given right line be the chord, ſine, tangent or ſecant, of any certain number of degrees, as ſuppſe 20, and the radius be ſought; open the ſector to the length of the given line in the points 20 and 20 of the lines of chords, ſines, tangents, or ſecants, according as the ſaid line is either chord, ſine, tangent or ſecant; and the diſtance between 60 and 60 on the chords, between 90 and 90 on the ſines, between 45 and 45 on the tangents, and between 0 and 0 on the ſecants, ſhall be the radius to the given line, whether it be chord, ſine, tangent or ſecant.

This may ſuffice to ſhew the nature, general uſe, and excellence of this inſtrument; it evidently appearing from what has been ſaid, that the *Sector* is a kind of univerſal *Plane Scale*, to any radius not greater than the extent of the inſtrument itſelf, when quite open, or leſs than the diſtance between the numbers at the ends of the reſpective lines, when quite ſhut.

And as the two lines of every pair make equal angles with each other reſpectively, they are thereby adapted for working proportions in equal parts and ſines, equal parts and tangents, *&c.* ſo that among other things the ſeveral caſes of plane Trigonometry may very readily be reſolved by the ſector. Some inſtances of which ſhall be hereafter given; but firſt I ſhall ſhew ſome particular uſes of the lines of lines, and of the lines of polygons.

Of the particular Uſe of the Lines of Lines.

As lines of equal parts, their uſe is the ſame with ſuch lines on common ſcales, ſerving to lay down any given length; but as they are laid down ſectorwiſe, they have other various uſes, ſome of the principal of which are ſhewn in the following problems.

PRO-

PROBLEM I.

To divide a given Line into any Number of equal Parts.

Take the extent of the given line between the feet of your compaſſes; then open the ſector to make that extent be a parallel between the legs, in the points expreſſing the number of parts into which the line is to be divided; ſo ſhall the parallel diſtance between 1 and 1, divide the given line into the parts required. For example, ſuppoſe the line AB were given to be divided into 6 equal parts; take the extent of the line AB, betwixt the feet of your compaſſes, and open the ſector to make this extent to be a parallel between the legs, in the points 6 and 6, and the parallel diſtance betwixt 1 and 1, *viz.* AC, ſhall be the $\frac{1}{6}$ part of the line AB.

Fig. 9.

If the given line be of too great extent to be applied to the legs of the ſector, take one half, or one fourth of it, which being divided as above directed, into the parts required, the double, or quadruple of one of thoſe parts, will accordingly divide the whole line into the number of parts propoſed.

PROBLEM II.

To divide a Line in the ſame manner as another is divided.

Lay down the divided line laterally on both ſides of the ſector, from the center, and mark the

point of its extenſion; then opening the ſector to the extent of the ſecond line, in the terms of the firſt; apply likewiſe the ſeveral parts of the firſt line laterally on the legs of the ſector, ſo ſhall the ſeveral parallels in the terms of thoſe parts, be the correſpondent parts in the line to be divided. Thus if the line CD were to be divided in the manner as the line AB; the
2 *Figs.* 10. extents of AB, AF, and AE, taken from the center laterally on both the lines of lines, which ſuppoſe on each line marked with B, F and E; then open the ſector to make the parallel BB equal to the line CD, ſo ſhall the parallels EE and FF, give the extent of CG and CH, in the line CD to be divided.

PROBLEM III.

To find the Proportion between two, or more given Lines.

The proportion between any given lines may be meaſured upon either of the lines of lines, as on other ſcales of equal parts, without opening the inſtrument. But to perform the operation ſectorwiſe, open the ſector ſo that the extent between 100 and 100, may be equal to one of the given lines; then taking the other line, or lines, ſeverally between your compaſſes, carry them with each extent along the legs of the ſector, parallel to the former, till both points reſt exactly on the ſame number in both the lines of lines, which number will give the proportion to 100, that each latter bears to the former. Thus if it were
Fig. 11. required to find the proportion between the lines AB and CD; open the ſector to

to make the extent between 100 and 100 equal to AB; apply the extent of the ſhorter line CD parallel to the former, and you will find the points to reſt on 80 and 80; the proportion therefore of CD to AB, is as 80 to 100; or in ſmaller numbers as 4 to 5.

If the greater line AB, be too long to be applied between 100 and 100, cut off AE upon the greater line, equal to CD, and the ſector being opened (as before directed) to make the extent between 100 and 100, equal to the part AE; then applying the extent of the part EB parallel to the former, you will find the points to reſt on 24 and 24; ſo that the proportion of the part EB, to the part AE, will be found to be as 24 to 100; therefore the proportion of the line CD, to the line AB, will this way be found to be, as 100 to 124.

PROBLEM IV.

To increaſe or diminiſh a Line in any given Proportion.

Open the ſector to make the extent between the firſt proportional number, on both the lines of lines equal the given line; then the parallel diſtance between the other proportional number on the ſame lines, will be the line ſought. Thus if the line A, is to be increaſed in the proportion of 3 to 7; open the ſector to make the diſtance between 3 and 3 equal the length of the line A; ſo ſhall the parallel diſtance betwixt 7 and 7, be the increaſed line B ſought. On the contrary, if the line B was to be diminiſhed in the proportion of 7 to 3; open the ſector to *Fig.* 12.

make the diſtance betwixt 7 and 7, equal the line B; then the parallel diſtance betwixt 3 and 3, ſhall be the diminiſhed line A ſought. Note, it may be ſometimes more convenient to work with the equimultiples of the numbers given, which will produce the ſame effect; thus for the proportion of 3 to 7, you may take the numbers 6 to 14, 9 to 27, 12 to 28, or 30 to 70, *&c.*

PROBLEM V.

To find a third Proportional to two given Lines.

Lay down both the given lines laterally on the legs of the ſector, obſerving the points of their extenſion; then taking the ſecond line between your compaſſes, open the ſector to its extent in the terms of the firſt line, ſo ſhall the parallel diſtance between the terms of the ſecond line, be the third proportional ſought. For example, let the two given lines be A and B, which being laid down on the ſides of the ſector from the center A, ſuppoſe the terms of the firſt line to be BB, and the terms of the ſecond CC; then opening the ſector in the terms BB, to the extent of the ſecond line B, the parallel diſtance between CC ſhall be the third proportional ſought. For as A is to B, ſo is BB (equal to the line B) to CC.

Fig. 13.

PROBLEM VI.

To find a fourth Proportional to three Lines given.

Let the firſt and third lines, be both laid down laterally on the legs of the ſector, from the center; then opening the ſector in the terms of the firſt line, to the extent of the ſecond line ; the parallel diſtance between the terms of the third line, ſhall be the fourth proportional. For example, let A, B and C, be the three lines given ; ſet off A and C on the ſides of the ſector, from the center A, marking the terms of their extenſion BB, and CC ; then taking the ſecond line B, open the ſector to its extent, in the terms of the firſt line A, *viz.* BB ; and the parallel diſtance betwixt CC, the terms of the third line C, ſhall be the fourth proportional ſought. *Fig.* 14.

Note, In geometry, as well as in arithmetick, it is not neceſſary, that all the proportionals be of one denomination ; but only that the fourth found correſpond with the ſecond, as the third with the firſt ; therefore the firſt and third proportionals may be meaſured by one ſcale, and the ſecond and fourth by another ; and to this end, a diagonal ſcale longer by an inch than the ſector, when opened, whoſe grand diviſions might be half-inches, with an inch at one end, and the half inch at the other, diagonally divided, would be better for uſe in the lateral extents, herein directed to be taken on the lines of lines, and a beam-compaſs for taking them off.

But a beam-compaſs ſcale divided into 30 and 40 parts in every inch throughout, and theſe again each ſub-divided by *Nonius*'s diviſions into ten parts, (that is, each inch into 300 and 400 parts) on the index carrying the moveable point, which ſets off any extent within its length, to the 800th part of an inch (or divided only into 20 parts in every inch, that may by two *Nonius*'s diviſions be again each ſub-divided into 20 and 50 parts, whereby each inch is divided into 400 and 1000 parts) is greatly to be preferred; and as the points in theſe are perpendicular, and have no ſpring, nor are liable to alter from the extent, they are readily and moſt exactly ſet to, by the means of an adjuſting ſcrew; is alſo on theſe accounts better than the other compaſſes, for determining the truer opening of the ſector, and for taking the parallel extents thereon, and eſpecially as with this beam-compaſs the given ſide or ſides may be taken to anſwer nearly to the extream opening of the ſector, by doubling, trebling, halving, *&c.* if needful, whereby the ſolutions in plane trigonometry, *&c.* will be had much nearer the truth, than when opened to a ſmall angle.

PROBLEM VII.

To find a right Line nearly equal to the circumference of a given Circle.

Since the proportion of the diameter of a circle to its circumference, is nearly as 3.183 to 10; therefore opening the ſector to make the diſtance between 3.183 on both lines of lines, equal the length of the diameter of the circle propoſed, the parallel diſtance between 10 and 10, will be the length of a line nearly equal to the circumference of the given circle.

PROBLEM VIII.

To open the Sector ſo that the two Lines of Lines (and conſequently the others reſpectively, if they are laid down as they ought, at equal angles) may ſtand at right angles with each other.

Since by the 47th peopoſition of the 1ſt book of *Euclid*, it is demonſtrated, that in a right-angled triangle, the ſquare of the hypothenuſe is equal to the ſum of the ſquares of both the legs; therefore, if the whole lateral length of one of the lines of lines, taken as 10 equal parts, be ſet over from 8 on one leg to 6 on the other, the two lines of lines (and conſequently the other pairs reſpectively) ſhall ſtand at right angles with each other; for 64 the ſquare of 8, added to 36 the ſquare of 6, makes 100, equal to the ſquare of 10.

With the beam-compaſs and ſector.

Open the ſector to make each pair of lines become one ſtraight line; then ſet the beam-compaſs to extend from 45 to 45 in the lines of ſines, or from 70.71 to 70.71 in the lines of lines, and this extent made a parallel radius between the ends of either of the ſaid pairs of lines, by moving them thereto, the two lines of every pair ſhall ſtand more truly at a right angle with each other.

To theſe few problems peculiar to the line of lines, I ſhall add one or two of a more general nature.

PROBLEM IX.

To open the Lines upon the Sector or the Edges of the Inſtrument itſelf to any propoſed Angle.

Take the quantity of the angle propoſed, laterally from the center on one of the lines of chords; then open the ſector to make this extent be a parallel betwixt 60 and 60 on the ſaid lines, ſo ſhall the two lines of chords, and of every other pair of lines, ſtand reſpectively with each other at the propoſed angle. Thus, to open the lines to an angle of 20 degrees, take from the center the lateral extent of 20 degrees on either line of chords; then open the ſector to make this extent be a parallel betwixt 60 and 60 on the ſaid lines; and the two lines of chords, and conſequently all the other pairs, each being laid down to the ſame angle, ſhall accordingly form an angle of 20 degrees, each with the other reſpectively. And if (as in the print prefix'd to this work) in every pair of lines, each line forms with the other an angle of 6 degrees, when the ſector is quite ſhut, it is but adding 6 degrees to the quantity of the angle propoſed, in taking the lateral extent, and the parallel ſo made, as above, ſhall ſet the edges of the inſtrument itſelf to the angle required.

Note, If the angle propoſed exceeds 60 degrees, open the ſector to make each pair of lines become one ſtraight line, and take with the beam-compaſs the parallel extent between the number of half the angle on each line of ſines; then move the ſector to make this extent a parallel radius between 90 and 90, at the ends of the ſaid lines, and ſo ſhall the two lines of every pair ſtand reſpectively with each other at the propoſed angle: But if the angle propoſed exceeds 120 degrees, the lines or the edges of the ſector may be more truly ſet thereto by the protractor.

PROBLEM X.

The Sector being opened, to find the Quantity of the Angle, which either the ſeveral Pairs of Lines, or the Edges of the Inſtrument, make with each other.

This problem is but the reverſe of the former: For if the parallel diſtance betwixt 60 and 60 on the line of chords, be applied laterally from the center on either of the ſaid lines, the degrees of its extenſion is the meaſure of the angle that each of the ſeveral pairs of lines makes with its correſponding one; deducting therefore 6 degrees from the quantity ſo found, for the angle that each of the ſeveral pairs of lines makes with its correſponding one, when the inſtrument is quite ſhut, and the remainder will be the quantity of the angle formed by the edges of the inſtrument. But if the angle was greater than 60 degrees, the parallel radius, applied in the lines of ſines, when the ſector is opened to make the two one ſtraight line, will give on both, at equal diſtance from the center, the degrees of half the angle the ſaid lines had made with each other.

Of the Uſe of the Lines of Polygons.

The lines of polygons are chiefly contrived for the ready diviſion of the circumference of a circle into any number of equal parts from 4 to 12, that is, as a ready means to inſcribe regular polygons of any given number of ſides, from 4 to 12, within a given circle: To do which, ſet off the radius of the given circle (which is always the ſide of the inſcribed hexagon) as a parallel betwixt 6 and 6, upon the ſaid lines, ſo ſhall the parallel diſtance betwixt 5 and 5, be the ſide of a pentagon; between 7 and 7, the ſide of a heptagon; between 8 and 8, the ſide of an octagon, *&c.* All which is too plain to need an example.

N. B. All ſuch regular polygons, whoſe number of ſides (exceeding five) will exactly divide 360 (which the circumference of every circle is) without a remainder, may likewiſe be very readily ſet off upon the circumference of a circle, from the lines of chords; for opening the ſector to make the extent of the radius of the circle, to be a parallel betwixt 60 and 60 on the lines of chords, and having divided 360 by the number of ſides, the parallel diſtance betwixt the number of the quotient on the ſaid lines, ſhall be the ſide of the polygon required; thus for an octagon, take the diſtance betwixt 45 and 45; and for a pentedecagon, the diſtance betwixt 24 and 24, *&c.*

If it be required to form a polygon upon a given right line; open the ſector to make the extent of the given line, to be a parallel betwixt the points on the lines of polygons, anſwering to the number of ſides of which the polygon is to conſiſt; as for a pentagon, betwixt 5 and 5; or for an octagon, betwixt 8 and 8; ſo ſhall the parallel diſtance betwixt 6 and 6, be the radius of a circle, whoſe circumference ſhall be divided by a given line, into the number of ſides required.

The lines of polygons are likewiſe uſeful in deſcribing upon any given line, an iſoſceles triangle, whoſe angles at the baſe ſhall each be double that at the vertex. For taking the given line betwixt your compaſſes, open the ſector till that extent reaches from 10 on one leg, to 10 on the other; then ſhall the parallel diſtance betwixt 6 and 6, be the length of the two equal ſides of the triangle ſought.

Before we proceed to the manner of working proportions upon the ſector, it will be neceſſary to conſider the nature of the lines of artificial numbers, ſines, and tangents; becauſe as the ſame proportions may likewiſe be work'd upon theſe artificial lines, ſo one method of working, will ſerve as a proof of the other.

Of the Lines of Artificial Numbers, Sines and Tangents.

Theſe ſeveral lines, which are uſually laid down upon ſectors parallel to the outward edges, in the ſame manner as upon other ſcales, are only the logarithms of the natural numbers, ſines, and tangents, thus transferred to a ſcale.

1. The line of numbers, or *Gunter*'s line, as it is commonly called, is a line of geometrical proportion, divided into 9 unequal parts, beginning at 1 towards the left hand, and number'd on with 2, 3, 4, 5, *&c.* to 9, next below 1 at the middle of the line; where another radius begins, and the ſame diviſions are repeated, and number'd on (as before) to 9 with 10, at the end of the line on the right hand. Each of theſe primes, or firſt

grand diviſions, are ſub-divided according to the ſame ratio, into 10 other parts, and each of theſe ſub-diviſions (if the line be of ſufficient length) ſhould again be ſub-divided into 10 other leſs parts. But upon pocket-ſectors, which when opened are but 12 inches in length, only the part from 1 in the middle, to 2 towards the right hand, is a ſecond time divided, and that but into 5 parts inſtead of 10, every one of which muſt therefore be accounted as 2 centeſms. In numbering therefore upon the line (wherein conſiſts the greateſt difficulty) the figures, 1, 2, 3, *&c.* which denote the primes, may be taken arbitrarily, either as units, tens, hundreds, or thouſands; or they may repreſent the tenth, hundredth, or thouſandth parts of an unit.

If 1 at the beginning of the line, be taken for unity, then 1 in the middle will be 10, and 10 at the end 100; but if the firſt 1 be accounted 10, then 1 in the middle will ſtand for 100, and 10 at the end for 1000; or, if the firſt 1 be reckon'd 100, then 1 in the middle will be 1000, and 10 at the end 10000; ſo that whatſoever value ſhall be put upon the firſt 1, the others will bear a like proportion.

When therefore the firſt 1 or prime, repreſents 10 units, the figures 2, 3, 4, *&c.* to 1 in the middle, will ſtand for 20, 30, 40, 50, 60, 70, 80, 90, 100, and each tenth, or ſub-diviſion in the firſt radius of the line, will ſignify 1 unit, and each centeſm, or ſecond ſub-diviſion (if there be any) will be $\frac{3}{10}$ parts of an unit; 1 in the middle will be (as before obſerved) 100, and the figures 2, 3, 4, *&c.* following 200, 300, 400, *&c.* each tenth, or ſub-diviſion in the ſecond radius, will denote 10 units, and each centeſm 1 unit. Again, let the firſt 1 repreſent 100, then the figures 2, 3, 4, &c. will ſignify 200, 300, 400, &c. and 1 in the middle 1000, and 10 at the end 10000; according to this ſuppoſition, in the firſt radius, each tenth of a prime will be 10 units, and each centeſm 1 unit; and in the ſecond radius, each tenth of a prime 100, and each centeſm 10.

In accounting decimal fractions upon the line; if 1 in the middle of the line be accounted as unity, then will each prime in the firſt radius denote 0,1, each tenth of a prime 0,01, and each centeſm 0,001. If 10 at the end of the line to the right hand, be accounted as unity, the whole firſt radius will repreſent 0,1, and the numbers 2, 3, 4, &c. in the ſecond radius 0,2, 0,3, 0,4, &c. and every prime in the firſt radius, and every tenth of a prime in the ſecond radius, will ſignify 0,01, or one hundredth part of unity, and every tenth of a prime in the firſt radius, or centeſm in the ſecond, will denote 0,001, or one thouſandth part of unity.

The numeration of the line thus explain'd, let it now be propoſed to find the point thereon anſwering to the number 436. For the 4 hundred, take the 4 firſt primes next the left hand; for the ſecond figure 3, take 3 tenths of the grand diviſion betwixt 4 and 5, and for the 6 units, reckon 6 centeſms, or 6 parts of the next tenth; ſo that the extent from 1 at the beginning of the line, to that point, will expreſs the number 436. The ſame point will likewiſe repreſent the numbers 43,6; 4,36; or 0,436; if the firſt 1 be accordingly accounted 10, 1, or $\frac{1}{10}$ of unity.

To multiply upon the line, extend your compaſſes from 1 at the beginning, to the point repreſenting the number of your multiplier, the ſame extent will reach from the number of your multiplicand, to the product; thus, if 125 were given to be multiplied by 42; extend the compaſſes from 1 to 42, and the ſame extent will reach from 125 to 5250.

To divide upon the line; extend the compaſſes backwards from the number of the diviſor, to unity; the ſame extent laid the ſame way will reach from the number of the dividend to the quotient: Thus if 5250 were given to be divided by 125; extend the compaſſes backwards from 125 to unity, the ſame extent will reach the ſame way, from 5250 to 42.

2. The line of artificial ſines, conſiſts only of the logarithms of the natural ſines, transferr'd from a table of logarithms to the ſcale; they are number'd from the left to the right, with the figures 1, 2, 3, *&c.* to 10, and ſo forward with 20, 30, 40, *&c.* to 90, at the end on the right. In the firſt part of the line, the grand diviſions each repreſent one degree, ſo that if each prime be ſub-divided into 12 parts (as they commonly are upon ſectors) each ſub-diviſion will ſignify 5 minutes. In the latter part of the line, the grand diviſions which are each 10 degrees, being ſub-divided into 10 parts, each ſub-diviſion will repreſent 1 degree, and according as they are again ſub-divided into 4, 3, or 2 parts, ſuch ſecond ſub-diviſions contain 15, 20, or 30 minutes each.

3. What has been ſaid of the line of ſines, is likewiſe to be underſtood of the line of artificial tangents, whoſe diviſions begin at 1, and is number'd 2, 3, &c. on to 10, in like manner as the ſines, ſignifying ſingle degrees; and in the ſecond part it runs on with 20, 30, &c. to 45, which ſtands at the end of the line, then theſe return back again to 89 where the line begins, as would be evident from the inſpection of the line itſelf, if it was number'd backward, as it ought to be, and in ſome that are large really are.

The uſe of theſe lines is in working proportions, whether arithmetical or geometrical; particularly they are of very ready ſervice in trigonometrical ſolutions.

The method of working with them is thus: In all proportions you have three terms given, to find a fourth. Seek out therefore the firſt term, whether number, ſine, or tangent, in its proper line; and on that point ſet one foot of your compaſſes, extending the other to the ſecond, or third term, which-ever of them is of the ſame name with the firſt; the ſame extent laid from the other term, the ſame way, will reach to the fourth term required.

Thus to work the following proportion; as the ſine of 52° 30′ to the number 85, ſo is radius, or the ſine of 90°, to the fourth number required. Set one foot of your compaſſes in the line of artificial ſines on 52° 30′, and extend the other foot to 90° on that line, the ſame extent will reach from 85 on the line of numbers to 107, the fourth number required. And thus are all queſtions in proportion work'd by the artificial lines of numbers, ſines and tangents; as will be more fully ſeen in the following ſection.

Obſerve, If the proportion to be taken is between two tangents, one greater, and the other leſs than 45 degrees, it muſt be taken by two extents of the compaſſes, *viz.* from the one to 45 degrees, and from 45 degrees back to the other; and theſe added, the ſum is the extent from one to the other.

Of the manner of working Proportions on the Sector; both by the conjoint uſe of the Lines of Lines, with the Lines of natural Sines, Tangents, &c. as alſo by the artificial Lines of Numbers, Sines and Tangents.

Having already in treating of the reaſon, and general uſe of this inſtrument, ſhewn the particular uſe of the ſeveral lines of chords, ſines, tangents, and ſecants laid down thereon, and how univerſal their application is thereby made, above what it is upon the plane ſcale: I now proceed to ſhew the conjoint uſe of the lines of lines, with the lines of natural ſines, and tangents, as they are laid down ſectorwiſe, and alſo the uſe of the artificial lines of numbers, ſines, and tangents, in working proportions; which I ſhall exemplify in the reſolution of the ſeveral caſes of plane Trigonometry, both right angled, and oblique angled.

The Seven Caſes of right-angled plane Triangles.

CASE I.

The angles, and one of the legs being given, to find the other leg.

Suppoſe in the triangle ABC, the angle A is 36 degrees, the baſe AB 75.4 feet, and it were required to find the height of the perpendicular BC. *Fig.* 15.

The trigonometrical proportion for working this caſe; is as radius, to the tangent of the angle A, ſo is the leg AB, to the leg BC.

To work which upon the ſectoral Lines.

Take with your compaſſes on either line of tangents, the tangent of 36° degrees laterally from the center; then open the ſector to make this extent a parallel between 45 and 45 on the lines of tangents; now take with your compaſſes on the lines of lines, the parallel extent betwixt 75.4 and 75.4 the length of the given leg, which extent applied laterally from the center on either line of lines, will reach to 54,8, for the length of the other leg; ſo that the perpendicular BC, is thereby found to be 54,8 feet.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs by the ſcale of 30 or 40 in an inch, at any multiple of the given leg, not exceeding the whole opened length of the ſectoral lines, and open the ſector to make it a parallel radius between 45 and 45 at the end of the lines of tangents; then take the parallel extent between 36 and 36 in the ſaid lines, and the compaſs ſcale will give the ſame multiple of the leg required, as was taken off the given leg.

Upon the artificial Lines.

Set one foot of your compaſſes on 45, or (the radius) at the end of the line of tangents, and extend the other backwards to 36; the ſame extent will reach on the line of numbers, from 75.4, the length of the given leg AB, to 54.8, the length of the required leg BC.

CASE II.

The Angles, and one of the Legs being given, to find the Hypothenuſe.

Suppoſe in the former triangle, the baſe AB, as before, 75,4 feet, the angle A 36 degrees, and conſequently the angle C 54 degrees; it were required to find the length of the hypothenuſe AC.

Proportion. As the ſine of the angle C, to the radius; ſo is the baſe, to the hypothenuſe.

To work which upon the ſectoral Line.

Take with your compaſſes the whole length of either line of ſines, for the radius or ſine of 90 degrees, (the quantity of the angle B) laterally from the center, and open the ſector to make this extent a parallel betwixt 54 and 54 on the lines of ſines; then take with your compaſſes on the lines of lines, the parallel diſtance betwixt 75,4 and 75,4, the length of the baſe, and this extent laterally applied on either line of lines, will meaſure 93,2, the length of the hypothenuſe ſought.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs by the ſcale of 30 in an inch, at 200 (or any multiple of 100) and open the ſector to make this extent a parallel between 54 and 54 on the lines of ſines; then take the parallel extent between 75,4 and 75,4, in the lines of lines, and the ſaid ſcale will give the double (or other multiple) of the hypothenuſe required.

Upon the artificial Lines.

Set one foot of your compaſſes on 54 (the ſine of the angle C) in the line of ſines, and extend the other to 90 at the end; the ſame extent will reach on the line of numbers, from 75,4, the length of the baſe, to 93,2, the length of the hypothenuſe required.

CASE III.

The Hypothenuſe and Angles being given, to find either of the Legs.

Suppoſe in the foregoing triangle, the hypothenuſe AC 93,2, the angle A 36 degrees, and conſequently the angle C 54 degrees; and it were required to find the length of the baſe AB.

Proportion. As radius to the ſine of the angle C, ſo is the hypothenuſe to the baſe.

To work which upon the ſectoral Lines.

Set one foot of your compaſſes on the center, and extend the other laterally to 54 degrees on either line of ſines; then open the ſector to make this extent a parallel betwixt 90 and 90 on the lines of ſines; now take the parallel diſtance between 93,2 and 93,2, on the lines of lines, and this diſtance applied laterally from the center on either line of lines, will reach 75,4, for the length of the baſe required.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs by either ſcale at any multiple of the hypothenuſe, near the whole length of the opened ſectoral lines, and open the ſector to make it a parallel radius between 90 and 90, at the end of the lines of ſines; then take the parallel extent between 54 and 54, in the ſaid lines, and the ſcale will give an equal multiple of the baſe required.

Upon the artificial Lines.

Set one foot of your compaſſes on 90 at the end of the line of ſines, and extend the other backwards to 54, the ſine of the angle C; the ſame extent will reach on the line of numbers, from 93,2, the length of the hypothenuſe, backwards to 75,4, the length of the baſe required.

CASE IV.

The Legs being given, to find the Angles.

In the foregoing triangle ſuppoſe the baſe AB, 75,4 feet, the perpendicular BC 54,8 feet, and it were required to find the quantities of the angles A and C.

Proportion. As the leg AB to the leg BC; ſo is radius, to the tangent of the angle at A: whoſe complement to a quadrant will be the angle at C.

To work which upon the ſectoral Lines.

Setting one foot of your compaſſes on the center, extend the other laterally on one of the lines of lines to 54,8, the length of the perpendicular BC; then open the ſector to make this extent a parallel between 75,4 and 75,4, on the ſaid lines; the ſector being thus opened, take with your compaſſes the parallel radius, or extent between 45 and 45, on the lines of tangents; then this extent taken laterally on either line of tangents, will give 36°, for the quantity of the angle A, and 36° ſubtracted from 90°, will leave 54°, for the quantity of the angle C.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs by either ſcale at any multiple of the greater leg, near the whole length of the opened ſectoral lines, and open the ſector to make this extent a parallel radius between 45 and

45, at the end of the lines of tangents; then ſet the beam-compaſs to the ſame multiple of the leſſer leg, and this extent taken parallelwiſe on the ſaid lines, where the points will reſt in like numbers, gives the leſſer angle, and its complement is the greater angle.

Upon the artificial Lines.

Set one foot of your compaſſes on the line of numbers, in 75,4, the length of the baſe, and extend the other backwards to 54,8, the length of the perpendicular; the ſame extent will reach from 45 (radius) at the end of the tangents, to 36 the tangent of the angle A; and alſo to 54 the tangent of the angle C, if in the line of numbers, it had been taken forwards from 54,8 to 75,4; for (as before obſerved) the tangents ſhould be number'd increaſing backwards the ſame as forwards.

CASE V.

The Legs given, to find the Hypothenuſe.

Suppoſe in the foregoing triangle, the baſe AB is 75,4, and the perpendicular BC 54,8, it were required to find the length of the hypothenuſe AC.

To work this Caſe upon the ſectoral Lines.

Open the inſtrument to a right angle, (by Prob. the 18th on the uſes of the lines of lines;) then taking between your compaſſes, the ſlant extent from 75,4, in one of the ſaid lines of lines, to 54,8, in the other, apply the ſaid extent laterally from the center, on either of the ſaid lines, and you will find 93,2, for the length of the hypothenuſe required.

Upon the artificial Lines.

Firſt, find the angles by caſe the 4th, then the hypothenuſe, by caſe the 2d.

CASE VI.

The Hypothenuſe and one of the Legs given, to find the Angles.

Suppoſe in the foregoing triangle, the hypothenuſe AC 93,2, and the baſe AB 75,4, it were required to find the angles A and C.

Proportion. As the hypothenuſe to the baſe, ſo is radius to the ſine of the angle at C.

To work which upon the ſectoral Lines.

Setting one foot of your compaſſes in the center, extend the other laterally on either line of lines to 93,2, the length of the hypothenuſe AC; then open the ſector to make this extent a parallel radius betwixt 90 and 90, on the lines of ſines; again, ſetting one foot of your compaſſes in the center, extend the other laterally on either line of lines to 75,4, the length of the baſe AB; this extent run parallelwiſe on the lines of ſines, till the feet reſt in like numbers, gives 54 degrees, the quantity of the angle C, oppoſite to the baſe, which being ſubtracted from 90, there will remain 36 degrees, for the quantity of the angle A.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs by either ſcale at any multiple of the hypothenuſe, near the whole length of the opened ſectoral lines, and open the ſector to make this extent a parallel radius between 90 and 90, at the end of the lines of ſines; then ſet the beam-compaſs to the ſame multiple of the given leg, and this extent taken parallelwiſe on the ſaid lines, where the points reſt in like numbers, gives the oppoſed angle, and its complement is the other angle.

Upon the artificial Lines.

Set one foot of your compaſſes upon the line of numbers, in 93,2, the length of the hypothenuſe, and extend the other backwards to 75,4, the length of the baſe; the ſame extent will reach from 90 at the end of the line of ſines, backwards to 54, the ſine of the angle C, and 54 ſubtracted from 90, leaves 36 for the angle A.

CASE VII.

The Hypothenuſe, and one of the Legs, being given, to find the other Leg.

Suppoſe in the foregoing triangle, the hypothenuſe AC 93,2, the baſe AB 75,4, and it were required to find the perpendicular BC.

To work this caſe upon the ſectoral Lines.

Open the ſector to a right angle, by *Prob.* the 8th, on the uſes of the lines of lines; then ſetting one foot of your compaſſes in the center, extend the other laterally on either line of lines, to 93,2, the length of the hypothenuſe AC; with this extent ſetting one foot in 75,4, the length of the baſe AB, on one line, the other foot will cut the other line in 54,8, the length of the perpendicular BC required.

Upon the artificial Lines.

Firſt, find the angles, by *Caſe* the VIth; then to find the length of the perpendicular, ſet one foot of your compaſſes on 90 at the end of the line of ſines, and extend the other backwards to 36, the ſine of the angle A; the ſame extent will reach on the line of numbers from 93,2, the length of the hypothenuſe, backwards to 54,8, the length of the perpendicular required.

The Six Caſes of oblique-angled plane Triangles.

CASE I.

Two ſides, and an angle oppoſite to one of them, being given, to find the other oppoſite angle.

Suppoſe in the triangle ABC, the ſide AC 65 leagues, the ſide BC 54,1 leagues, and the angle A oppoſite to the ſide BC 35° 30′, required the quantity of the angle B. *Fig.* 16.

Proportion. As the ſide oppoſite to the given angle, to the ſine of the given angle, ſo is the ſide oppoſite to the angle ſought to the ſine of the angle required.

To work which upon the ſectoral Lines.

Setting one foot of your compaſſes on the center, extend the other laterally on either line of lines to 54,1, the length of the ſide BC; then open the ſector to make this extent a parallel betwixt 35° 30′, and 35° 30′ on the lines of ſines; again, ſetting one foot of your compaſſes in the center, extend the other laterally on either line of lines to 65, the length of the ſide AC; this extent run parallelwiſe on the lines of ſines, till the feet reſt in like numbers, gives 44° 15′ nearly; for the quantity of the angle B, oppoſite to the ſide AC.

If you would know the quantity of the remaining angle C, ſubtract the ſum of the angles A and B from 180 degrees (the ſum of the three angles of every triangle) and the remainder 100° 15′, ſhall be the quantity of the angle C.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs to any multiple of the ſide oppoſed to the given angle, not exceeding the greateſt parallel between 35° 30′ and 35° 30′, on the lines of ſines, and open the ſector to make the ſaid parallel fit thereto; then ſet the beam-compaſs to the ſame multiple of the other given ſide, and this extent taken parallelwiſe on the ſaid lines, where the points will reſt in like numbers, gives the angle required.

Upon the artificial Lines.

Set one foot of your compaſſes on the line of numbers in 54,1, the length of the ſide BC, oppoſite to the given angle A, and extend the other to 65, the length of the ſide AC; the ſame extent will reach on the line of ſines, from 35° 30′, the given angle A, to 44° 15′, the quantity of the required angle B.

CASE II.

The angles, and one ſide being given, to find either of the other ſides.

Suppoſe in the foregoing triangle, the ſide BC as before, being 54,1 leagues, the angle A 35° 30′, the angle B 44° 15′, and the angle C 100° 15′, required the ſides AB and AC.

Proportion. As the ſine of the angle oppoſite to the given ſide, to the ſide given; ſo is the ſine of the angle oppoſite to the required ſide, to the ſide required.

N. B. When an obtuſe angle is given, you muſt work by it's complement to 180 degrees, which is commonly called it's ſupplement.

To work this caſe upon the ſectoral lines.

Setting one foot of your compaſſes on the center, extend the other laterally on either line of lines to 54,1, the length of the given ſide BC; then open

the

the ſector to make this extent a parallel between 35° 30′, (the angle A) and 35° 30′ on the lines of ſines; the ſector being thus opened, take with your compaſſes the parallel diſtance between 44° 15′, (the angle B) and 44° 15′ on the lines of ſines, and applying the ſaid diſtance laterally on either line of lines, it will give 65, for the length of the ſide AC. So likewiſe the parallel diſtance between 79° 45′, (the ſupplement of the angle C) and 79° 45 on the lines of ſines, will, when applied laterally on either line of lines, give 91,7, for the length of the ſide AB.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs to any multiple of the given ſide, not exceeding the greateſt parallel between 35° 30′ and 35° 30′ on the lines of ſines, and open the ſector to make the ſaid parallel fit thereto; then take the parallel extent between the numbers of either of the other angles, on the ſaid lines, and the ſcale will give the ſame multiple of the ſide oppoſed to the angle taken.

Upon the artificial Lines.

Set one foot of your compaſſes on the lines of ſines in 35° 30′, the quantity of the angle A, oppoſite to the given ſide BC, and extend the other to 44° 15′, the quantity of the angle B; the ſame extent will reach on the line of numbers from 54,1, the length of the given ſide BC, to 65, the length of the required ſide AC. Or, ſetting the firſt foot (as before) in 35° 30′ on the ſines, extend the other to 79° 45′, (the complement of 100° 15′ to 180°) the ſame extent will reach on the line of numbers, from 54,1 to 91,7, the length of the oppoſite ſide AB.

CASE III.

Two ſides, and an angle oppoſite to one of them being given, to find the other ſide.

Suppoſe in the foregoing triangle, the ſide AC 65 leagues, the ſide BC 54,1 leagues, and the angle A oppoſite to the ſide BC 35° 30′, it were required to find the ſide AB.

To work this caſe either upon the ſectoral or artificial Lines.

1. Find the angles, by Caſe the firſt.
2. The ſide, by Caſe the ſecond.

CASE IV, and V.

Two ſides, and the contained angle being given, to find the other two oppoſite angles, and the other ſide.

Suppoſe in the foregoing triangle, the ſide AC as before, 65 leagues, the ſide AB 91,7 leagues, and the contained angle A 35° 30′, it were required to find the other oppoſite angles B and C, with the ſide BC.

The proportion for finding the angles in this caſe is as follows, viz. As the ſum of the two ſides AC and AB, to their difference, ſo is the tangent of half the ſum of the angles B and C, *viz.* 72° 15′, to the tangent of half their difference; which, added to their half ſum, gives the greater angle C, but ſubtracted from the ſaid half ſum, leaves the leſſer angle B.

N. B. The ſum of the angles B and C, is found by ſubtracting the given angle A, *viz.* 35° 30′ from 180°.

To work theſe Caſes upon the ſectoral Lines.

Theſe two caſes are taken together, becauſe upon the ſectoral lines it is moſt convenient to find the length of the third ſide, before the angles. To find therefore the length of the ſide BC, take the quantity of the given angle A 35° 30′, laterally on one of the lines of chords, and open the ſector to make this extent a parallel betwixt 60 and 60, on the ſaid lines; with the ſector thus opened, ſet one foot of your compaſſes in 91,7 (the length of the ſide AB) on one of the lines of lines, and extend the other to 65 (the length of the other given ſide AC) on the other line of lines; this extent meaſured laterally from the center, on either line of lines, will give 54,1, for the length of the required ſide BC: Then may the quantity of either of the required angles be found by caſe the firſt, which added to the given angle, and the ſum ſubtracted from 180, the remainder will be the uantity of the other angle.

With the Beam-compaſs and ſectoral Lines.

Set the beam compaſs to the ſum of the two given ſides, or any multiple thereof, not exceeding the greateſt parallel between the numbers of the half ſum of the two oppoſite angles, on the lines of tangents; then ſet the beam-compaſs to the difference of the two given ſides, or the like multiple thereof; and this extent taken parallelwiſe on the ſaid lines, where the points reſt in like numbers, gives the half difference of the two oppoſite angles, but if the line of quarter-tangents was taken with the line of the two ſides, then multiply the difference of the ſaid two ſides, or it's multiple by four, and the half difference of the two angles will be given on the lines of the larger tangents.

Upon the artificial Lines.

Firſt, to find the angles. Set one foot of your compaſſes upon the line of numbers in 156,7 (the ſum of the ſides AB and AC) and extend the other backwards to 26,7 (the difference of the ſides;) this extent divided into two parts, one that will reach on the line of tangents from 72° 15′ (half the ſum of the angles B and C) to 45°, the other part will reach from 45° back to 28°, which added to 72° 15′, gives 100° 15′, for the greater angle C; and ſubtracted from 72° 15′, leaves 44° 15′, for the leſſer angle B. The angles thus found, the ſide BC may be obtained by caſe 2.

CASE VI.

The three ſides being given, to find the Angles.

Suppoſe in the foregoing triangle the ſide AB 91,7 leagues, the ſide AC 65 leagues, the ſide BC 54,1 leagues, and it were required to find the angles.

To work this caſe upon the ſectoral Lines.

Firſt, to find the angle A; the two ſides which include it, are AB 91,7 and AC 65; take the extent of the third ſide BC 54,1 between your compaſſes, laterally on either line of lines; then ſet one foot in 91,7 on one of the ſaid lines, and open the ſector till the other foot falls on 65, in the other line of lines; the ſector thus opened, take with your compaſſes, the parallel radius, *viz.* the extent betwixt 60 and 60 on the lines of chords; this extent meaſured laterally on either line of chords, will give the quantity of the angle A, *viz.* 35° 30′. The angle B may either be found by the ſame method, from the three given ſides, or by the help of the diſcover'd angle A, according to the method laid down in caſe 1.

The two angles A and B thus found, ſubtract their ſum from 180°, the remainder will be the quantity of the third angle C.

With the Beam-compaſs and ſectoral Lines.

Set the beam-compaſs by its ſcale, either to the baſe, or the ſum of the two leſs ſides, and open the ſector to make the extent a parallel between the numbers of the ſum of the two leſs ſides, or of the baſe, on the lines of lines; then ſet the beam-compaſs to any multiple of the difference of the ſaid two ſides, by the ſame ſcale, or to the parallel extent between the nnmbers thereof on the ſaid lines, and this extents will on the ſaid lines, where the points reſt in like numbers, or on the ſaid compaſs ſcale, give the ſame multiple of the difference of the ſegments of the baſe, but in proportion to the ſum of the ſaid two ſides. In this example, ſetting the beam-compaſs to 238.2=2×119.1, I open the ſector, and make it a parallel between 91.7 and 91.7 in the lines of lines, now I take the parallel extent between 87.2 (= 8 × 10.9) and 87.2 in the ſaid lines, and the compaſs ſcale gives 226.5 = 16 × 14.156 ×.

Upon the artificial Lines.

To work this caſe upon the artificial lines: Firſt, divide the baſe, or longeſt ſide AB, into two ſegments, by a perpendicular let fall from the oppoſite angle C; the value of which ſegments are diſcoverable by the following proportion, *viz.* As the true baſe to the ſum of the other two ſides, ſo is the difference of the ſaid two ſides to the difference of the ſegments of the baſe: Which difference added to the true baſe, will give the double of the greater ſegment; but ſubtracted, will leave the double of the leſſer ſegment.

Set therefore one foot of your compaſſes on the line of numbers in 91,7, the length of the true baſe, and extend the other to 119,1, the ſum of the two other ſides; the ſame extent will reach on the ſame line, from 10,9 the difference of the ſides, to 14,157, the difference of the ſegments of the baſe; which difference 14,157 added to the true baſe 91,7 gives 105,857, the double of the greater ſegment; but ſubtracted, leaves 77,543, the double of the leſſer ſegment.

The triangle therefore being divided into two rectangled triangles, by the perpendicular, and the ſegments of the baſe thus found, the angles may be obtained by caſe the 6th of rectangled plain triangles.

I have now, I preſume, ſufficiently exemplified the uſes of the ſeveral lines laid down upon the modern ſectors, tho' beſides what I have mentioned, they are capable of various applications, in menſuration, architecture, dialling, aſtronomy, *&c.* But as formerly other lines uſed to be put upon them, and ſtill the *French* ſectors are furniſhed with lines of ſuperficies and ſolids, *&c.* and my Author too having in his *Practical Geometry*, treated of theſe two lines, which I there omitted, with reference to this appendix; I ſhall here, from him, give the manner of their projection and application.

Projection of the lines of ſuperficies.

Let the lines AE AE repreſent the lines of ſuperficies, to divide which, having a ſcale of 1000 equal parts of the ſame length as the intended lines, take thereſrom 125 parts equal $\frac{1}{8}$ of 1000*, which ſet off from the center A, as the firſt diviſion upon each; 250 parts equal $\frac{1}{4}$ of 1000 ſet off from A, will be the fourth diviſion; the mean proportion between 125 and 250, will be the number of parts marking the ſecond diviſion; the ſum of 125 and 250 equal 375 parts, taken from the ſcale, and ſet off from the center A, will reach to the ninth diviſion; the third diviſion will be the mean proportion between 125 and 375: again 625 parts will give the 25th diviſion; and the mean proportion between 125 and 625, will be the fifth diviſion, *&c.* laſtly, 1000 parts will be the 64th diviſion: All which is plain from the conſideration, that ſimilar ſurfaces are in a duplicate ratio of their homologous ſides.

Fig. 17.

Uſe of the Line of ſuperficies.

Taking between the points of your compaſſes the radius of a circle, or the ſide of any plane figure, and ſetting it as a parallel betwixt 1 and 1, the firſt diviſion from the center; ſo ſhall the parallel extent betwixt 2 and 2, give you the radius of a circle, or ſide of a figure of a double area; and betwixt 3 and 3 triple, *&c.*

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* *This ſuppoſes the whole length of* 1000 *equal parts to anſwer to* 64, *as in the figure.*

In the ſame manner may be found circles, and other plane figures ſubdouble, ſubtriple, &c.

Projection of the lines of ſolids.

Let the lines AF AF repreſent the lines of ſolids: From the ſaid ſcale of 1000 equal parts, ſet off from the centre A 250, for the firſt diviſion, and 500 for the 8th; then finding two mean proportionals betwixt 250 and 500, the firſt will give you the ſecond diviſion; and the ſecond the fourth: To find this firſt mean proportional, ſubtract the logarithm of 250 from the logarithm of 500, and adding the $\frac{1}{4}$ of what remains to the logarithm of 250, you will get the logarithm of the firſt mean proportional, which will be nearly 315; and if you add again the ſame $\frac{1}{3}$ to the logarithm of 315, you will have the logarithm of the ſecond mean proportional. For the third and ninth diviſions, take two mean proportionals between 250, and the triple thereof, 750; and for the 5th and 25th diviſions, take two mean proportionals between 250 and 1250, five times 250, &c. Laſtly, the whole 1000 equal parts, will be the 64th diviſion.

Uſe of the Lines of ſolids.

Set over the ſide of any body, as a parallel betwixt 1 and 1, the firſt diviſion on the lines of ſolids; and the parallel extent betwixt 2 and 2, ſhall give the homologous ſide of a ſimilar body, whoſe ſolid content ſhall be double; and ſo the ſeveral other diviſions will accordingly give ſides of bodies triple, quadruple, &c. or ſub-double, ſub-triple, ſub-quadruple, &c.

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